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Destruction of Dioxin-Contaminated Solids and Liquids by Mobile Incineration

Enviresponse, Inc., Livingston, NJ

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DESTRUCTION OF DIOXIN-CONTAMINATED SOLIDS AND LIQUIDS BY MOBILE INCINERATION

by

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EPA Contract 68-03-3255

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16. ABSTRACT

The EPA Mobile Incineration System, which consists of a kiln, secondary combustion chamber, air pollution control unit, and separate continuous stack gas analysis capabilities, was rigorously tested in 1982-1983 using PCB-contaminated liquids and other chlorinated organic fluids. Destruction and removal efficiencies of at least 99.9999% were consistently attained at a heat release of 106J/hr.

As a result of these favorable performance data, a project was initiated to evaluate the technical, economic, and administrative feasibility of on-site incineration of dioxin-contaminated materials. During 1984, the system was extensively modified for field use and performance-tested with a variety of uncontaminated soils and other solid wastes at the EPA facility in Edison, NJ.

Based on the results of laboratory and pilot plant studies conducted to establish optimum kiln conditions and the available literature, the EPA system was judged to be more than adequate for detoxifying dioxin-contaminated solids and liquids, and thus could be expected to accomplish a successful dioxin trial burn. Accordingly, the system was transported in December 1984 to the Denney Farm site in McDowell, Missouri, which had been selected for the trial burn in the intervening months.

Destruction and removal efficiencies exceeding 99.9999% were achieved for 2,3,7,8-TCDD during a trial burn on dioxin-contaminated liquids and solids conducted in April, 1985. The kiln ash and process wastewater byproducts had no detectable dioxins and were in accordance with guidelines identified by EPA's Office of Solid Waste.

A field demonstration on a variety of dioxin-contaminated materials was conducted between July 1985 and February 1986. A total of 0.9 million kg of solids and 81,600 kg of liquids was successfully decontaminated during that time. Operations were suspended on February 6, 1986 pending Superfund reauthorization. When operations resume, the Field Demonstration will be completed and a second trial burn will take place on materials designated by the Resource Conservation and Recovery Act and the Toxic Substances Control Act.

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This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report summarizes an evaluation of incineration for on-site treatment of hazardous substances and dioxin-contaminated materials at a waste site. The evaluation showed that incineration can achieve dioxin destruction and removal efficiencies greater than 99.9999%, and that byproduct ash and water can be "delisted." The information in this report is useful to those who are concerned with the cleanup of hazardous waste sites.

For further information, please contact the Land Pollution Control Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Hauser, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

This final report describes the evaluation of an EPA-developed on-site mobile incineration system for treatment of hazardous wastes. Dioxin-contaminated wastes were used for the evaluation, with a research objective of less than 1 ppb residual dioxin in treated soils.

The Mobile Incineration System had previously (1982-1983) been tested using PCB-contaminated liquids, and destruction and removal efficiencies of 99.9999% were achieved. Following extensive modifications, including the addition of a solids feed system, the modified incineration system was shaken down at Edison, NJ. Permit documentation, operating and safety protocols, and site modification planning were prepared. Laboratory and pilot plant studies carried out to establish optimum conditions for decontaminating soils indicated that the conditions necessary to decontaminate soils thermally could be achieved in the EPA incinerator. Therefore, after the appropriate permits were obtained, the system was transported to southwestern Missouri, given a field shakedown, and a trial burn on dioxin-contaminated liquids and soils was conducted.

The trial burn on dioxins was successful, with destruction and removal efficiencies exceeding 99.9999%. During these tests, 3.84 lb of dioxin, contained in 1,750 gallons of liquids and over 40 tons of solids were destroyed. Resource Conservation and Recovery Act (RCRA) and Missouri State particulate emission limitations (180 mg/Nm^3 @ 7% O_2) were met in three of four test runs. The fourth run exceeded the limit slightly, apparently due to the accumulation of fine particles in the air pollution control system. Subsequent modifications were made, and additional stack gas testing indicated that particulate emissions were reduced to below permitted levels.

The treated soil and process wastewater byproducts from the Dioxin Trial Burn were analyzed according to a set of guidelines provided by the EPA Office of Solid Waste (OSW). These byproducts met the guidelines and are considered nonhazardous by OSW. An "Exclusion Notice" delisting these byproducts from the RCRA designation was published in the Federal Register on July 25, 1985.

A field demonstration on a variety of dioxin-contaminated liquids and solids was conducted between July 1985 and February 1986. A total of 2.0 million pounds of solid materials and 180,000 pounds of liquids were successfully decontaminated during that time. Operations were suspended on February 6, 1986 pending Superfund reauthorization. When operations at the site resume, the Field Demonstration will be completed and a second trial burn on RCRA- and Toxic Substances Control Act (TSCA)-designated materials will take place. However, with the publication of this report, extensive documentation is being made available publicly to encourage commercial application of the technology of on-site incineration for the cleanup of Superfund-designated sites.

This report was submitted in fulfillment of Contract Number 68-03-3255 by Enviresponse, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from February, 1984 to February, 1986, and work was completed as of April 15, 1987.

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ABBREVIATIONS AND SYMBOLS

MM Btu	Million British thermal units
CAA	Clean Air Act
CDD	Chlorinated dibenzo-dioxins
CDF	Chlorinated dibenzo-furans
CHEAF	Cleanable high efficiency air filter
Cu yd	Cubic yards
DRE	Destruction and removal efficiency
EI	Enviresponse, Incorporated
EMSL-LV	Environmental Monitoring Support Laboratory-Las Vegas
gal	Gallons
HEPA	High efficiency particulate air filter
HMB	Heat and material balance
HP	Horsepower
HT	Heat transfer
IT	IT Corporation
kg	Kilograms
kJ	Kilojoules
kW	Kilowatts
L	Liters
m	Meters
MDNR	Missouri Department of Natural Resources
mg	Milligrams
ml	Milliliters
u	Micron
ug	Micrograms
MIS	Mobile Incineration System
ND	Not detected
NEPA	National Environmental Policy Act
ng	Nanograms
Nm^3	Normal cubic metres
NPDES	National Pollutant Discharge Elimination System
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PCBs	Polychlorinated biphenyls
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per trillion
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCB	Releases Control Branch
RCRA	Resource Conservation and Recovery Act
S/A	Sampling and analysis
SCC	Secondary Combustion Chamber
SCFM	Standard cubic feet per minute
TCDD	Tetrachlorodibenzo-p-dioxin
TSCA	Toxic Substances Control Act
t	Metric ton (tonne)

CONVERSIONS

To Convert From	To	Multiply By
Btu/lb	J/g	2.326 E+00
Cu ft	m^3	2.832 E-02
Cu yd	m^3	7.646 E-01
ft	m	3.048 E-01
°F	°C	$t_C=(t_F-32)/1.8$
gal	m^3	3.785 E-03
HP	kW	7.46 E-01
lb	kg	4.535 E-01
tons	t	9.072 E-01
MM Btu/hr	GJ/hr	1.055 E+00

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The project to evaluate mobile incineration of dioxin-contaminated soils in Missouri has involved personnel from many organizations who worked intensely over 26 months.

The project was initiated by Morris Kay, Regional Administrator for Region VII. Support for Regional activities was provided by many additional personnel, including Dr. Ralph Hazel, Rowena Michaels, Stephen Wurtz, Dr. Robert Kleopfer, William Bunn, David Tripp, Joseph Galbraith and Gary Kepko.

The technical aspects of the project were managed by Frank Freestone of the Releases Control Branch (located at Edison, NJ) of EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio. Support at the Edison, NJ, office was provided by Ira Wilder, Dr. John Brugger, James Yezzi, Richard Traver, and Uwe Frank.

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IT Corporation (EERU Operating Contractor from June 1, 1981 through August 31, 1985), and Enviresponse, Incorporated (the current EERU contractor), had primary responsibility for preparing all of the administrative materials and for operating the incineration system. Richard Miller was Project Manager for IT, and Helge Mortensen for EI. Principal support from IT included Charles Pfrommer, Ralph Lovell, Kenneth Honeycutt, Frank Coffman, William Seeman, Thomas Hernon, Thomas Vash, Jack Yanoso, James Adinolfi, Dr. Lionel Domash, Steve Josher, Robert Harned, Carl Thomas, Walter Berger, Richard Lynch, Edward Alperin, Jeffrey Flemming, David Pitts, Richard Helsel, William Troxler, Barry Stevenson, William Anderson, Matthew Plautz, Thomas Busmann, Wayne Potter, Cyril Henke, Fred Beattie, William Bosack, and Corey Briggs. Principal support from EI included Dr. Alan Sherman, Dr. A.C. Gangadharan, Al Dahlgren, Dave Turkington, Paul Faccone, Anthony Dirienzo, Christopher Marlowe, and Tony Mack.

At the Missouri Department of Natural Resources, Jefferson City, MO, Thomas Pauling and Scott Boyd provided regulatory review and oversight.

At Syntex, Inc., Raymond Forrester, Glen Davis and Kent Stormer provided advice and support.

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SECTION 1

INTRODUCTION

The discovery of abandoned hazardous waste sites as a result of Superfund investigations has placed increasing pressure on the U.S. Environmental Protection Agency to find alternative solutions to the problems of treating and disposing of toxic and hazardous wastes. The decreasing availability of landfill sites combined with the increasing public opposition to the transport of toxic and hazardous wastes have added to the pressure. The treatment and disposal problem is particularly acute in the case of dioxins. In recognition of these difficulties, EPA's "Dioxin Strategy" (dated November 28, 1983) recommended that high-temperature incineration undergo further detailed evaluation by the Office of Research and Development (ORD) as a potential dioxin treatment method. High-temperature incineration is an acceptable method for the destruction of hazardous substances cited under the Resource Conservation and Recovery Act regulations and of PCBs as identified by the Toxic Substances Control Act regulations.

Accordingly, the ORD Releases Control Branch (RCB), a component of the Hazardous Waste Engineering Research Laboratory (HWERL), at the request of Morris Kay, Regional Administrator for Region VII, embarked on a field validation project aimed at evaluating the existing EPA-developed Mobile Incineration System (MIS) for the on-site treatment and disposal of toxic and hazardous wastes, with specific concern for soils contaminated with 2,3,7,8-TCDD. This project is part of an ongoing Superfund-sponsored program to evaluate and offer for commercialization processes, methods, and prototype devices for on-site cleanup of Superfund sites. Specifically, the purpose of this research is to determine the economic feasibility of the technique and to establish: (a) test burn protocols; (b) health and safety protocol; (c) site specific, risk assessment protocol; (d) an economic model for estimating the cost of treatment per unit of material processed; and (e) national and state permit protocol.

This is a summary report on the evaluation of the use of the EPA MIS for on-site treatment of hazardous substances and dioxin-contaminated materials. The project design (February, 1984) included laboratory testing followed by field testing. The incineration-related laboratory work was very promising. Thus, the MIS was prepared for field operations and has been used to conduct a very carefully controlled trial burn on dioxin-contaminated liquid and solid materials at the Denney Farm site in southwestern Missouri. Full field validation tests on a variety of dioxin-contaminated feeds began in July, 1985. The Field Demonstration continued until February 1986, when it was suspended pending Superfund reauthorization.

This summary report includes detailed chronological descriptions of the activities of this project, detailed laboratory study information on the MIS, including the minimum times and temperatures for thermally removing dioxins from soils. Detailed analyses of lessons learned from the field operations with the MIS are provided. The report contains a summary of Trial Burn reports arising from the liquids and solids trial burns (Appendix A); photographs of the system are found in Appendix B. The report also contains an annotated index (Appendix C) to the additional documentation related to this project, including detailed permit application materials (for RCRA, TSCA, and NEPA), delisting documentation, the risk assessment, detailed operation and maintenance manuals for the MIS, and safety manuals for field operations. The index also includes detailed plans and specifications for reproducing the MIS (including detailed cost estimates), the detailed plans and specifications for the field installation, Trial Burn reports arising from the liquids and solids trial burns, and a comparison with a modular, transportable incineration system. All documentation will be publicly available. Additional data and operating information arising from operation after February 1986 will be available in later documents.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The EPA Mobile Incineration System was evaluated with both laboratory and full-scale programs and shows promise as a tool for hazardous waste cleanup by achieving a dioxin destruction and removal efficiency (DRE) greater than 99.9999%, and by decontaminating soil to less than 0.2 ppb residual dioxin. Further, the process wastewater and treated soil from the incinerator have been analyzed for a series of specific constituents considered as likely contaminants and have met the guidelines established by the Office of Solid Waste. The treated soil and process wastewater were, therefore, "delisted" from RCRA designation, under guidelines published in the Federal Register [F.R., Vol. 50, No. 143, July 25, 1985].

Mobile and "transportable" incinerators appear to be practical alternatives for on-site cleanup of dioxin-contaminated soils and liquids. The technical aspects of incineration are well developed and are used commonly in industry.

From an economic viewpoint, future improvements in the design and capacity of mobile and transportable systems can be expected to provide economically feasible cleanup for Superfund and other waste sites.

The use of on-site systems is viable from the viewpoints of State and Federal regulatory agencies. Permit issuance can be expedited, and the public, if provided with information on the project, will react positively even to incineration of 2,3,7,8-TCDD.

The extended Field Demonstration of the Mobile Incineration System began in July 1985. A variety of contaminated solids and liquids were treated by the unit. By February 1986, over two million pounds of solid materials had been successfully decontaminated. Operations were temporarily suspended at the end of February 1986, pending Superfund reauthorization. When operations resume the Field Demonstration will be completed.

During the period following suspension of the Field Demonstration, a design study was conducted by EI to increase the throughput and on-stream factor of the MIS. The proposed modifications (which include increasing the capacity of the ram feed system, incorporating an oxygen enrichment system, installation of a cyclone, and replacement of the CHEAF with a new scrubbing system) are expected to increase the solids feeding capacity of the MIS by a factor of three to five times its current level.

Many important lessons concerning design, operation, and maintenance were learned during the Trial Burn and extended Field Demonstration of the MIS in Missouri. Generally, these "lessons learned" were independent of incineration technology and apply to most field operations involving complex equipment. Most "lessons" revolved around the need to plan carefully for the wide variety of weather conditions found in Missouri, for the problems caused by mechanical failures of the equipment, and for the specific nature of the materials fed to the MIS. The need for adequate site preparation became very apparent when heavy rains and a thaw caused the gravel roads constructed for the project to give way, trapping heavy equipment and other vehicles. The subzero cold weather in Missouri during the Trial Burn caused a number of mechanical failures in the system. There was also an apparent need for a larger waste water storage area as the rate of generation was significantly greater than planned. The need to resolve problems caused by mechanical design factors quickly became an important lesson when significant increases in solids entrainment from the kiln to the SCC (as a result of changes in composition of the feed) began to hamper operations and limit the on-stream availability of the MIS.

The costs of processing waste materials by the MIS were divided in three general catagories, namely, capital costs, mobilization and demobilization costs, and operating costs. The unit cost ($/ton) of processing depends primarily on the operating costs. Labor costs were found to be the largest fraction (66%) of the total operating costs. Mobilization and demobilization costs occur each time the MIS is relocated to a new site. These costs were found to be approximately 3 times the initial capital and startup costs based on a total of 8 relocations involved during our assumed 15 year life of the MIS. Since these costs are highly site-dependent, efforts should be made to minimize these costs by proper site selection where ever possible. Sites with existing roadway, buildings, available water/electric power etc., are less costly. Cleanup plans could benefit from consideration of cleanup of "clusters" of sites in order to minimize the mobilization and demobilization costs.

SECTION 3

MOBILE INCINERATION SYSTEM

BACKGROUND

The Mobile Incineration System consists of a refractory-lined rotary kiln, a secondary combustion chamber, and air pollution control equipment mounted on three heavy-duty semi-trailers. Monitoring equipment is carried by a smaller trailer. Other ancillary equipment is assembled at the site as needed (Figure 1).

LIQUID TRIAL BURN

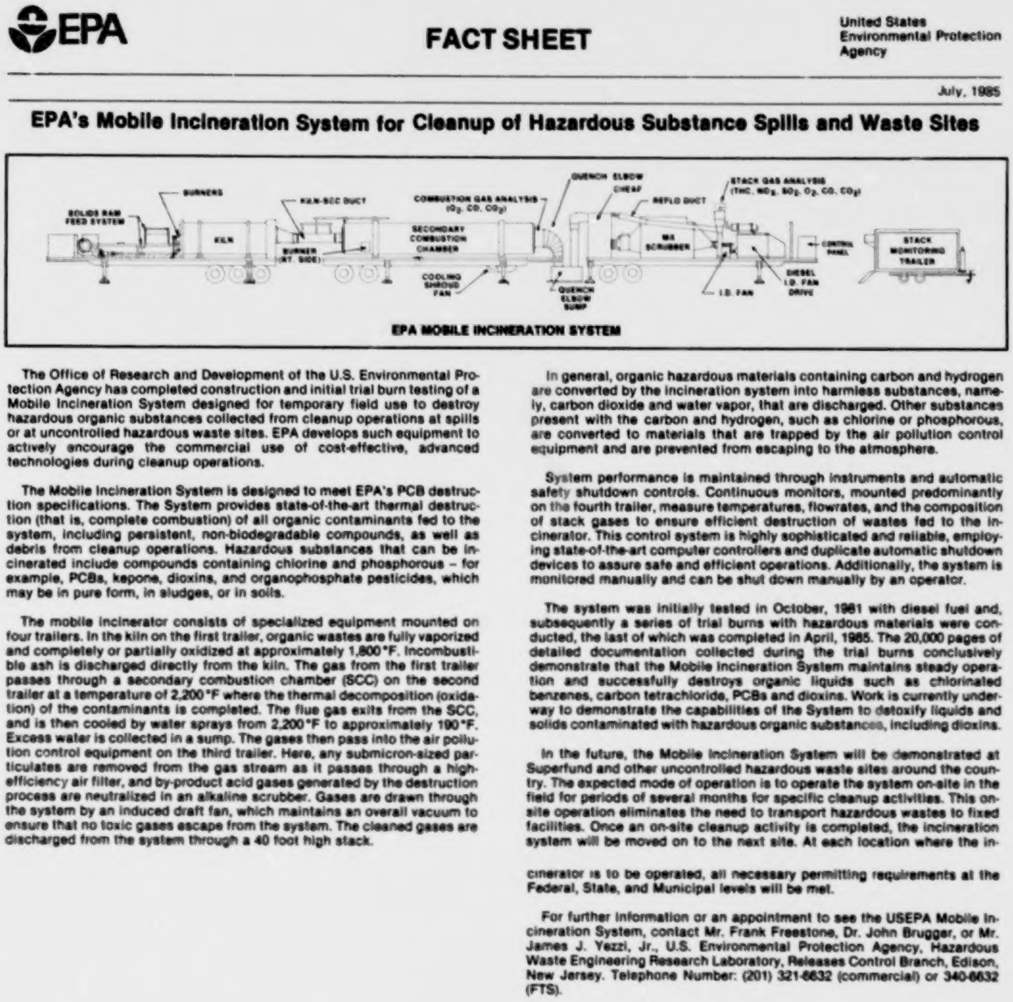
The ability of the MIS to destroy toxic and hazardous liquid organic wastes and to comply with applicable Federal and State regulations was demonstrated with a Liquid Trial Burn. The Trial Burn consisted of five tests which were conducted in three phases from September 1982 through January 1983 at the EPA facility in Edison, NJ. The tests evaluated the ability of the MIS to destroy tetrachloromethane (carbon tetrachloride), dichlorobenzene, trichlorobenzenes, tetrachlorobenzenes, and PCBs while controlling the emissions of HCl and particulate matter. Twenty-five test runs were conducted, during which the incinerator's operating conditions were monitored and an extensive sampling and analytical program was conducted. Federal and/or State observers were on site throughout the entire Trial Burn to ensure that the incineration system was operated safely and in accordance with the Trial Burn permits.

The high combustion and destruction efficiencies measured during the Liquid Trial Burn clearly demonstrated that the EPA Mobile Incineration System is an effective device for the destruction of hazardous organic material. In fact, the level of combustion and destruction reported was based on analytical limitations of measurement rather than on the actual finding of hazardous components in the stack emissions. The results of the Trial Burn indicated that the system met or exceeded all applicable Federal requirements for incineration systems (Table 1) (1,2). Following the Liquid Trial Burn, plans to ship the MIS to Missouri were begun.

MISSOURI PROJECT DESIGN

The project design for evaluation of the MIS in Missouri included the following elements:

Planning and permits, including the preparation of contractor's detailed work plans; site selection, preparation of applications for Federal site selection, and State (Missouri Department of Natural Resources, MDNR) permits; preparation of "delisting petitions" for assuring the cleanliness of MIS solid and liquid byproducts for both the Trial Burn and the Field Demonstration; preparation of a risk assessment of MIS operations on dioxins, and a "Health Survey" (required by MDNR).


SOLIDS RAM FEED SYSTEM
BURNERS
KILN
KILN-SCC DUCT
BURNER (RT. SIDE)
COMBUSTION GAS ANALYSIS (O₂, CO, CO₂)
SECONDARY COMBUSTION CHAMBER
COOLING SHROUD FAN
QUENCH ELBOW
QUENCH ELBOW SUMP
CHEAF
REFLO DUCT
MS SCRUBBER
STACK GAS ANALYSIS (THC, NOx, SO₂, O₂, CO, CO₂)
I.D. FAN
DIESEL I.D. FAN DRIVE
CONTROL PANEL
STACK MONITORING TRAILER

EPA

FACT SHEET

United States
Environmental Protection
Agency

July, 1985

EPA's Mobile Incineration System for Cleanup of Hazardous Substance Spills and Waste Sites

EPA MOBILE INCINERATION SYSTEM

The Office of Research and Development of the U.S. Environmental Protection Agency has completed construction and initial trial burn testing of a Mobile Incineration System designed for temporary field use to destroy hazardous organic substances collected from cleanup operations at spills or at uncontrolled hazardous waste sites. EPA develops such equipment to actively encourage the commercial use of cost-effective, advanced technologies during cleanup operations.

The Mobile Incineration System is designed to meet EPA's PCB destruction specifications. The System provides state-of-the-art thermal destruction (that is, complete combustion) of all organic contaminants fed to the system, including persistent, non-biodegradable compounds, as well as debris from cleanup operations. Hazardous substances that can be incinerated include compounds containing chlorine and phosphorous – for example, PCBs, kepone, dioxins, and organophosphate pesticides, which may be in pure form, in sludges, or in soils.

The mobile incinerator consists of specialized equipment mounted on four trailers. In the kiln on the first trailer, organic wastes are fully vaporized and completely or partially oxidized at approximately 1,800°F. Incombustible ash is discharged directly from the kiln. The gas from the first trailer passes through a secondary combustion chamber (SCC) on the second trailer at a temperature of 2,200°F where the thermal decomposition (oxidation) of the contaminants is completed. The flue gas exits from the SCC, and is then cooled by water sprays from 2,200°F to approximately 190°F. Excess water is collected in a sump. The gases then pass into the air pollution control equipment on the third trailer. Here, any submicron-sized particulates are removed from the gas stream as it passes through a high-efficiency air filter, and by-product acid gases generated by the destruction process are neutralized in an alkaline scrubber. Gases are drawn through the system by an induced draft fan, which maintains an overall vacuum to ensure that no toxic gases escape from the system. The cleaned gases are discharged from the system through a 40 foot high stack.

In general, organic hazardous materials containing carbon and hydrogen are converted by the incineration system into harmless substances, namely, carbon dioxide and water vapor, that are discharged. Other substances present with the carbon and hydrogen, such as chlorine or phosphorous, are converted to materials that are trapped by the air pollution control equipment and are prevented from escaping to the atmosphere.

System performance is maintained through instruments and automatic safety shutdown controls. Continuous monitors, mounted predominantly on the fourth trailer, measure temperatures, flowrates, and the composition of stack gases to ensure efficient destruction of wastes fed to the incinerator. This control system is highly sophisticated and reliable, employing state-of-the-art computer controllers and duplicate automatic shutdown devices to assure safe and efficient operations. Additionally, the system is monitored manually and can be shut down manually by an operator.

The system was initially tested in October, 1981 with diesel fuel and, subsequently a series of trial burns with hazardous materials were conducted, the last of which was completed in April, 1985. The 20,000 pages of detailed documentation collected during the trial burns conclusively demonstrate that the Mobile Incineration System maintains steady operation and successfully destroys organic liquids such as chlorinated benzenes, carbon tetrachloride, PCBs and dioxins. Work is currently underway to demonstrate the capabilities of the System to detoxify liquids and solids contaminated with hazardous organic substances, including dioxins.

In the future, the Mobile Incineration System will be demonstrated at Superfund and other uncontrolled hazardous waste sites around the country. The expected mode of operation is to operate the system on-site in the field for periods of several months for specific cleanup activities. This on-site operation eliminates the need to transport hazardous wastes to fixed facilities. Once an on-site cleanup activity is completed, the incineration system will be moved on to the next site. At each location where the incinerator is to be operated, all necessary permitting requirements at the Federal, State, and Municipal levels will be met.

For further information or an appointment to see the USEPA Mobile Incineration System, contact Mr. Frank Freestone, Dr. John Brugger, or Mr. James J. Yezzi, Jr., U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Releases Control Branch, Edison, New Jersey. Telephone Number: (201) 321-6632 (commercial) or 340-6632 (FTS).

Figure 1. EPA Mobile Incineration System Fact Sheet

TABLE 1. RESULTS OF LIQUID TRIAL BURN

Parameter	Reg. Limit	1[a]	2[b]	3[c]	4[d]	5[e]
Kiln						
Temp., °C		900	890	900	980	960
SCC						
Temp., °C	1200±100[f]	1180	1180	1190	1220	1250
O_2, %	3[f]	7.5	8.8	8.0	7.2	6.9
Ret. Time, sec	2[f]	1.96	2.10	2.06	1.97	2.03
Combustion Eff., %	99.9[f]	99.999	99.999	99.999	99.999	99.999
HCl Removal Eff., %	99[g]			99.95	99.98	99.99
DRE						
CCl_4*	99.999[g]			99.99996		
DiClB	99.99			99.99998		
TriClB	99.99				99.9998	99.99993
TetraClB	99.99				99.9994	99.9998
PCB	h				99.9998	99.99991
Particulate mg/Nm^3@ 7% O_2	180[g]	6.9	22.1	64.9	35.2	42.7

[a] Test 1 fuel oil only - baseline - all results average of 3 test runs
[b] Test 2 1.2% Iron oxide in fuel oil for particulate test
[c] Test 3 21% CCl_4, 29% DiClB in fuel oil
[d] Test 4 11% Askarel in fuel oil
[e] Test 5 39% Askarel in fuel oil
[f] TSCA
[g] RCRA
[h] No DRE limit for liquid PCB
* CCl_4 = Tetrachloromethane; DiClB = o-Dichlorobenzene; TriClB = Trichlorobenzene; TetraClB = Tetrachlorobenzene; PCB = Polychlorinated biphenyls.

Legal and public relations activities conducted by EPA Region VII, including complex negotiations and preparation of a contract with Syntex Inc. (legally involved with the disposal of the dioxin wastes at the Denney Farm), and community relations activities to inform fully an interested public and to promote public participation;

Modifications to the MIS, including general modifications affecting refractory, burner controls, the monitoring system, and the electrical system; and the design, specification, procurement, installation, and shakedown of a solids feed system;

Laboratory and pilot studies, including bench and pilot scale tests to determine if the MIS would be capable of decontaminating soils to residual dioxin levels below approximately 1 ppb;

Operating procedures and operator training, including the updating of detailed operating and maintenance manuals, the revision of the safety manual for specific site operations, and operator training in operations and safety;

Site preparation and logistics, including planning and design of the site installation and all logistical considerations for operation of the MIS at a field location;

Field shakedown and preliminary testing, including testing of the MIS in the field in Missouri in preparation for the Trial Burn;

Plan and execute a RCRA/TSCA/Dioxins Trial Burn, including detailed sampling and analysis plans and QA/QC plans, to provide all performance data necessary to meet regulatory requirements for use of the MIS in Missouri and for all future Superfund site requirements; QA/QC reviews and guidance were provided by the Quality Assurance Division, EMSL-LV, ORD;

Plan and execute a Field Demonstration with the objective of providing longer-term operating information on costs and effectiveness for a variety of solid and liquid feeds.

PLANNING AND PERMITS

The first step toward field operations was selection of a site for the demonstration. Agreements were reached in April 1984 to operate the Mobile Incineration System on the Denney Farm near McDowell, MO, where over 90 drums of buried dioxin-contaminated wastes had been excavated and stored in a diked shelter. A second covered concrete basin on the site contained over 240 cubic yards of soil that had become contaminated when the buried drums leaked. The site was considered desirable by Syntex (current owner of the wastes), EPA Region VII, the Missouri Department of Natural Resources (MDNR), and HWERL because of its remoteness - approximately one mile off the public road, and in a rural area.

From a technical viewpoint, the site was the only location known in the USA where dioxin-contaminated materials existed in sufficient quantity (total dioxin needed: 1 kg) and in sufficient concentration ($>$200 ppm) to enable EPA to conduct a trial burn to verify a 99.9999% destruction and removal efficiency (DRE), using low-resolution gas chromatography-mass spectroscopy (GC-MS) as the analytical methodology for stack samples. A wide variety of dioxin-contaminated wastes, such as soils, liquids, drums, trash, and chemical solids were on the site that could be used to demonstrate the versatility of the MIS. A variety of soil types was also nearby for demonstrating that incineration can decontaminate most dioxin-containing soils found in Missouri.

Once the site had been selected, applications were prepared for a number of Federal and State permits. Some of the activities that previously took place in connection with obtaining permits for the Liquid Trial Burn in Edison, NJ, facilitated permitting in Missouri. The applicable permits and related documents were:

Clean Air Act (CAA)

EPA Region II found that the controlled emissions of applicable pollutants by the Mobile Incineration System are less than 250 tons per year; therefore, the system is not subject to the Prevention of Significant Air Quality Deterioration requirements of the Clean Air Act. This determination was accepted by Region VII as applicable to the Denney Farm site.

Toxic Substances Control Act (TSCA)

A TSCA permit for the Mobile Incineration System to burn liquid PCBs in Region II was obtained from there in 1983. An application for a PCB-solids trial burn was submitted to the EPA Office of Toxic Substances. Successful completion of the TSCA-solids demonstration tests at the Denney Farm will result in a nationally applicable TSCA permit for PCB liquids (using data from the previous Liquids Trial Burn) and PCB solids. This TSCA-solids demonstration is currently planned to follow completion of the Field Demonstration.

National Environmental Policy Act (NEPA)

On September 24, 1984, after submission of detailed NEPA compliance materials, a "Finding of No Significant Impact" was published in the Federal Register (3) for the Mobile Incineration System, granting the unit nationwide NEPA compliance. (See Appendix C, National Environmental Policy Act Application).

Resource Conservation and Recovery Act (RCRA)

A RCRA permit was issued by Region VII in October, 1984. Only a minimal amount of time elapsed (93 working days, 4.5 months) between the submission by HWERL of the initial application and issuance of the permit (conditioned on a satisfactory Trial Burn) due to the previously-acquired RCRA permit from Region II (1983), the full cooperation of the Region VII staff, and the help of the MDNR staff. The predominant focus of RCRA and MDNR permits was on the quality of the stack gas emission. Solids (ash) and liquid (scrubber water) byproduct quality was treated separately in a "Delisting Petition" under RCRA and MDNR rules (see below).

National Pollutant Discharge Elimination System (NPDES)

An NPDES permit was not applied for in Region VII because it was decided to have the byproduct process water generated by the unit "delisted" from regulatory control and to use land application as the disposal method.

State Permits

A Hazardous Waste Management Facility Permit and an Incinerator Permit for Air Pollution Control were issued by MDNR in October 1984, based on the same application submitted for the RCRA permit. This permit application included a Health Survey (an analysis of the current health of the population around the Denney Farm site) required by MDNR regulations. The cooperation of the MDNR permit review staff enabled this state permit to follow essentially the same schedule as the RCRA permit. That schedule included a coordinated State-Federal public hearing.

Delisting

The RCRA regulations, as implemented, identify byproducts from hazardous waste treatment systems as being hazardous unless and until they are proven to be nonhazardous and, therefore, specifically removed from the list of RCRA-designated waste ("delisted"). Removal of a specific byproduct from RCRA designation as "hazardous" is accomplished by EPA's Office of Solid Waste (OSW) publishing an "Exclusion Notice" in The Federal Register for 30 days, receiving public comments, and making a final decision regarding delisting. The application by an incinerator operator to have specific byproduct materials "delisted" is called a "Delisting Petition."

A delisting petition was filed with the EPA-OSW and MDNR, and was based on the prediction that the solid and liquid byproducts from the MIS operation would not pose a hazard to human health or to the environment. Data from the Trial Burn at the Denney Farm subsequently demonstrated that the incineration system byproducts met applicable guidelines for being nonhazardous. These guidelines were established by the EPA Office of Solid Waste (Table 2), and, with minor modifications were applicable to the Field Demonstration. A key feature of the delisting petition was data that established that the Trial Burn feed and byproduct samples were representative of materials intended to be fed and produced during the Field Demonstration.

Risk Assessment

As a supplement to the permitting process, an assessment of the cancer risks associated with the incineration of dioxin at Denney Farm was prepared by the Exposure Assessment Group of the EPA ORD, using several computer programs that take into account wind speed and direction, population distribution, and stack

TABLE 2. MDNR AND USEPA DELISTING PARAMETERS (FOR TRIAL BURN ONLY)

A. Per 40 CFR 261 Subpart C

	Ash Solids	Scrubber Waste Liquids
Ignitability	N.A.[a]	N.A.[b]
Corrosivity	pH = 2.0-12.5	pH = 2.0-12.5
Reactivity	Not reactive with water	Not reactive with water
EP Toxicity	As per 40 CFR, 261.24, Table 1, and App. II, except mercury[c]	ICP scan-heavy metals, except mercury as per Table 1[c]

B. Specific Substances

Toxic Constituent[d]	Delisting Target Values Solids	 Scrubber Water	Measured Value (Det. Limit) Solids	 Scrubber Water
Dioxins/Dibenzofurans[e]	1 ppb	10 ppt	ND (0.11 ppb)	ND (3.6 ppt)
2,3,4-Trichlorophenol	100 ppm	10 ppm	ND (1.0 ppm)	ND (50 ppb)
2,4,5-Trichlorophenol	100 ppm	10 ppm	ND (1.0 ppm)	ND (50 ppb)
2,4,6-Trichlorophenol	1 ppm	50 ppb	ND (0.2 ppm)	ND (10 ppb)
2,5-Dichlorophenol	350 ppb	15 ppb	ND (0.2 ppm)	ND (10 ppb)
3,4-Dichlorophenol	100 ppm	10 ppm	ND (0.2 ppm)	ND (10 ppb)
2,3,4,5-Tetrachlorophenol	1 ppm	50 ppb	ND (1.0 ppm)	ND (50 ppb)
2,3,4,6-Tetrachlorophenol	1 ppm	50 ppb	ND (1.0 ppm)	ND (50 ppb)
1,2,4,5-Tetrachlorobenzene	100 ppm	10 ppm	ND (1.0 ppm)	ND (50 ppb)
1,2,3,5-Tetrachlorobenzene	100 ppm	10 ppm	ND (1.0 ppm)	ND (50 ppb)
Hexachlorophene	200 ppm	5 ppm	ND (10 ppm)	ND (500 ppb)
Polychlorinated Biphenyls	2 ppm	1 ppm	ND (2.0 ppm)	ND (1 ppb)
Benz(a)pyrene	5 ppm	10 ppb	ND (0.2 ppm)	ND (10 ppb)
Benz(a)anthracene	5 ppm	10 ppb	ND (0.2 ppm)	ND (10 ppb)
Chrysene	50 ppm	1 ppm	ND (0.2 ppm)	ND (10 ppb)
Dibenzo(a,h)anthracene	5 ppm	10 ppb	ND (0.2 ppm)	ND (10 ppb)
Indeno(1,2,3-c,d)pyrene	5 ppm	10 ppb	ND (0.2 ppm)	ND (10 ppb)
Benz(b)fluoranthene	5 ppm	10 ppb	ND (0.2 ppm)	ND (10 ppb)

[a] The ash would not be ignitable after having passed through a kiln and having reached approximately 750°C at the time of discharge.

[b] The scrubber waste liquid, water, is not ignitable.

[c] Analysis will be for the following metals: Arsenic, Barium, Cadmium, Chromium, Lead, Nickel, Selenium, Silver.

[d] As per correspondence: Lee Thomas to Morris Kay, Oct. 22, 1984; Jack McGraw to Morris Kay, Jan. 18, 1985 and April 1, 1985.

[e] Weighted average of tetra-, penta-, and hexa-isomers using weighting factors related to toxicity.

emissions. Two cases were considered: one in which the DRE was zero, i.e., all of the dioxin in the feed is emitted from the stack; and a second case in which a DRE of 99.9999% was assumed.

The first case, an unrealistic, extremely conservative situation (DRE = 0), indicated that 2.3×10^{-3} "excess cancer cases" would result from the Trial Burn. For the second case, which is based on a more realistic assumption (DRE = 99.9999), the risk was calculated at 2.3×10^{-9} "excess cancers." The risk associated with the Field Demonstration would be three orders of magnitude less than that of the Trial Burn, since the feed concentration of dioxin is three orders of magnitude lower. These risks were considered reasonable for the activity.

LEGAL AND PUBLIC RELATIONS ACTIVITIES

Legal Arrangements

The activities at the Denney Farm site thus far have required contractural agreements between the two principal parties, the EPA and Syntex Agribusiness, Inc. (Syntex), and between the EPA's operating contractors, IT Corporation and Enviresponse, Incorporated, and both principal parties. Three interdependent agreements exist. IT's activities for the EPA between March 1, 1984 and August 31, 1985 were conducted under contract number 68-03-3069, dated June 29, 1981; specific activities pertaining to the MIS were further defined by Work Assignments under the contract. Similarly, EI's activities for the EPA have been conducted under contract number 68-03-3255, dated July 1, 1985; activities relating to the MIS were also defined by Work Assignments.

The EPA and Syntex are bound by an agreement dated October 31, 1984. Syntex's principal interest is in having the wastes for which it is responsible destroyed during the EPA-sponsored demonstration, and to have further materials destroyed during "Phase II" (an option for Syntex to use the MIS to dispose of additional Syntex-owned wastes). In addition, by way of contribution to the project, Syntex agreed to provide site improvements for incinerator operations (see Site Planning and Preparations, below).

An agreement between IT Corporation and Syntex became effective on October 30, 1984, and was largely subordinate to the EPA-Syntex agreements.

The agreements with Syntex define and limit their liabilities. They also define the extent of site improvements made by Syntex and the conditions of payment for these improvements. In the event that certain designated wastes are not successfully destroyed or that the resulting solid and liquid byproducts are not delisted, EPA must reimburse Syntex for certain costs associated with site improvements.

Additionally, an existing access agreement between EPA Region VII and the landowner, the James Denney family, was modified to enable operations to take place at the farm. These complex arrangements among Syntex, IT, EI, and the Denneys were negotiated by Region VII's legal counsel with technical advice from HWERL and EPA contractors.

Public Relations Activities

As a result of concerted community relations activities conducted by Region VII, the MIS was welcomed in Missouri, and was operated by EPA in an atmosphere of increasing public acceptance of incineration. The community activities included press conferences, presentations to civic organizations, an open house and tour of the site installation prior to operations, the legally required RCRA/MDNR permit public hearing, and a "technical day" during which preliminary trial burn data were released to the public and a site tour was conducted for interested parties. Additionally, a public information office was maintained at the Denny Farm site and was staffed during normal working hours every day of incinerator operations. These activities were critical to the overall success of the project, and received the personal attention of the Regional Administrator.

Public information activities continued during the operation of the incinerator in 1985, and on November 7, 1985, a public hearing was held in Cassville, Missouri to request a one-year extension of the State and Federal permits. This hearing was covered by the three local TV networks and the Missouri press. All comments made at the hearing favored the continued operation of the incinerator; there were no negative comments. The permit extensions were granted and the Field Demonstration was continued.

MODIFICATIONS TO THE MOBILE INCINERATION SYSTEM

General Modifications Made Prior to the Missouri Operation

A number of modifications were made to the MIS before it was moved to Missouri, based on the experience gained during the Liquid Trial Burn and on the specific requirements (i.e., solids handling) for planned operations in Missouri. The original refractory lining of the rotary kiln, A.P. Green "Kast-O-Lite-30," a medium-density, insulating, gun-applied, castable refractory, was replaced with A.P. Green "Jade Pack-88P," a ramable plastic phosphate-bonded refractory that was more resistant to abrasion, acid attack, and repeated thermal cycling. In addition, the refractory lining of the secondary combustion chamber ("Kast-O-Lite-30") was coated with a thin layer of A. P. Green "Jade-Set," an acid-resistant mortar.

The burner controls were modified to improve control and reliability. The continuous stack gas monitoring system was modified by the installation of an additional sampling probe in the quench duct and additional analytical instrumentation to provide a reliable backup unit for RCRA requirements for continuous monitoring of carbon monoxide and oxygen. The backup instruments use nondispersive infrared and polarographic analysis techniques, in contrast to the gas chromatography methods of the primary system.

Other modifications included changes in the electrical, piping, and kiln drive systems; addition of ladders and platforms for easier and safer access; regasketing of various connections; and cleaning and painting the entire system.

Solids Feed and Ash Discharge System

Since the Mobile Incineration System had been previously operated only on liquids, it was necessary to design, procure, and install a feed system, including a shredder, conveyor, weigh hopper, suitable for dioxin-contaminated solids and a HEPA/Carbon filter fugitive emission control system. Further, the ram feed and ash discharge systems were modified for more reliable operation.

The solids feed system has a shear-type shredder driven by a 150-HP hydraulic motor, and is capable of reducing 55-gallon drums, drum overpacks, pallets, soils, etc. to a size small enough to fit through the ram feeder on the kiln. After being shredded, the solids are carried by a totally enclosed, inclined conveyor to the weigh hopper. The bottom of the microprocessor-controlled weigh hopper is a sliding knife gate that opens to allow the hopper to empty into the ram feeder trough. The ram feeder is hydraulically operated, and forces the material past a sliding gate into the kiln. The system deposits an average of 0.5 ft^3, or roughly 35 pounds of soils into the kiln on a cycle time of 55 sec. Discharged ash is received into unpainted 55-gallon drums that are manually moved on a roller conveyor. This ash system was adequate for a prototype demonstration, but not for long-term operations.

In the field, the building housing the shredder, the inclined conveyor and a hood over the ash discharge chute are all connected via ducting to a trailer-mounted, dual-manifold 3500 scfm HEPA/Carbon filter system for fugitive dust control. Thus, the entire solids feed system and the ash discharge system are operated under negative pressure to control dust emissions.

LABORATORY AND PILOT STUDIES

While the Mobile Incineration System was being modified and prepared for the Trial Burn and Field Demonstration in Missouri, a parallel project was undertaken to provide supporting data. Previous work by others (4-7) indicated that vaporized dioxins would be adequately destroyed in a secondary combustion chamber operated at 2200°F, 3% excess O_2 and with 2 seconds dwell time. The required conditions to evaporate or otherwise remove dioxins from soils, however, had yet to be specified. The goals of this research project were, therefore, to: 1) determine the time-temperature environment needed to meet the research objective of soil decontamination to less than 1 ppb residual dioxin, 2) determine if the needed conditions could be met within the operating limits of temperature and residence time of the Mobile Incineration System, and 3) develop a basis for selection of recommended operating conditions for the Trial Burn and Field Demonstration. If the laboratory study results were negative, the field activity would be delayed or cancelled. Therefore, the laboratory study results had to be provided prior to any significant commitment to site preparations or transportation of the incinerator.

The choice of candidate soils for this study was made by HWERL to include 1) soils from Denney Farm proposed for incineration during the Trial Burn and Field Demonstration and 2) Missouri soils from Piazza Road being studied at the same time for EPA ORD (dioxin removal studies) by Battelle-Columbus Laboratories. The Denney Farm soils were contaminated with trichlorophenol still bottoms and had an initial average concentration of 500-ppb 2,3,7,8-TCDD; the average initial contamination level of the Piazza Road soils was 338 ppb. The soil being studied was sampled and analyzed before and after a thin (2 mm) layer in a flat tray was heated in a purged oven at specified temperatures for specified times. The oven was a Lindberg Furnace, Model 51848, with an electronic temperature control and a 1600-watt heater system. It had a double-shell construction with interior surfaces made of molded aluminum-silicate insulation material. The oven could operate at temperatures up to 1100^{o}C with a relatively fast heat-up rate. The oven was purged with a continuous stream of nitrogen or air depending on the rate. In one experiment, a deeper (6-8 mm) layer of soil was employed, and in another, the soil was compacted to form a 5-cm cube to simulate an agglomerate of clay.

The extraction procedure originally proposed for this project was the standard "EPA Jar Extraction Procedure for the Determination of 2,3,7,8-TCDD from Soil and Sediment." This method involved weighing a 10-g (wet weight) aliquot of soil into a jar. This aliquot was spiked with 100-uL of an internal standard/surrogate mixture (50-ng ^{13}C-2,3,7,8-TCDD/10-ng ^{37}Cl-2,3,7,8-TCDD), mixed with 20-g anhydrous sodium sulfate, and allowed to stand overnight to equilibrate the mixture. The aliquot was then placed on a platform shaker for 3 hours, using a methanol/hexane solvent extraction mixture. The extracts were decanted through filter paper and concentrated to approximately 1-mL using KD-evaporation. This 1-mL extract was subsequently processed through appropriate cleanup techniques.

During this project, some thermally treated soil samples extracted with this method produced recoveries below the acceptable limits (40%) specified in the Quality Assurance Project Plan. Conversations with key EPA and IT personnel resulted in the design of a comparative study of alternative extraction methods. The extraction method was modified to include acid pretreatment of the soil and a Soxhlet extraction using benzene. All samples from this project were analyzed using the Soxhlet/benzene procedure; samples that had been previously analyzed using the jar extraction procedure were reanalyzed using the preferred extraction method. This extraction procedure, although not a standard EPA analytical protocol, was the best available for this application.

To aid in the removal of chemical interferences, the solvent extracts were cleaned up using dual-column liquid chromatography. The first column, consisting of acid-modified and neutral silica gels, eluted directly onto a second column containing neutral alumina. Detailed descriptions of the cleanup techniques employed can be found in the EPA reference "The Determination of 2,3,7,8-TCDD from Soil and Sediment," revised September 1983. The resulting extracts were concentrated to dryness and subsequently raised to 50 uL with a solution containing 11-ng ^{13}C-2,3,7,8- TCDD.

Determination of the concentration of dioxins and furans was made by mass spectrometry. Specifically, the solvent extracts after clean-up were analyzed using HRGC/LRMS scanning in the selected ion monitoring mode for enhanced sensitivity. The column used for this isomer-specific analysis was a 60-m SP2330 fused silica capillary column. Before analyzing the test samples, a seven-isomer performance mixture containing the six TCDD isomers that eluted closest to 2,3,7,8-TCDD was run. Conditions were adjusted in order to separate the 2,3,7,8-TCDD from any other isomers. In addition, a five point calibration was periodically run in triplicate, producing a 15-point calibration curve for both native 2,3,7,8-TCDD and ^{37}Cl-2,3,7,8-TCDD versus ^{13}C-2,3,7,8-TCDD. The mean response factor was used for all subsequent calculations. The shift standard analyzed on the same day as the sample had to produce a response factor within 10% of the 15-point calibration in order to be acceptable.

Based on the results obtained in this study, and of other relevant published information, the following conclusions were drawn:

1. Thermal treatment of two different contaminated Missouri soils at time and temperature conditions representative of the MIS kiln capabilities was successful in achieving 1 ppb or lower residual concentration of 2,3,7,8-TCDD. Concentrations of other chlorinated dioxin (CDD) or chlorinated furans (CDF) were likewise below the detection level of 1 ppb.

2. The primary variables affecting 2,3,7,8-TCDD removal efficiency are temperature and time (Table 3 and Figure 2). A correlation developed based on the primary study soil (Denney Farm) indicated an exponential dependence of residual 2,3,7,8-TCDD on both time and 2,3,7,8-TCDD vapor pressure, which is in turn exponentially dependent on temperature.

3. In general, other variables studied, including other process variables (e.g., composition and quantity of purge gas) and soil characteristics (e.g., initial moisture content and soil type), had a relatively minor or negligible influence on dioxin removal [see (4) for details]. However, the combination of very large soil agglomerates and high initial moisture required substantially longer residence times to achieve a specific temperature throughout the soil mass.

4. At high temperatures (approximately 600°C), major chemical and physical changes that undoubtedly influence the treatment process occur in various constituents of the soil. Even at the extreme low end of the temperature range that soils might experience in a rotary kiln (e.g., 500°C), low energy interactions (e.g., sorption) between a chemical and a soil apparently have only a minor influence on dioxin removal.

5. Translation of the laboratory results to predict MIS performance requires an accurate understanding of the heat transfer capabilities and characteristics of the system. Assuming constant uniform temperature of the soil and plug flow of the soil through a rotary kiln, estimated treatment conditions to achieve a residual concentration less than 1 ppb

TABLE 3. SUMMARY OF RESULTS DESCRIBING TIME-TEMPERATURE EFFECT ON REMOVAL OF 2,3,7,8-TCDD

Nominal Test Temperature (°C)	Time at Test Temperature[a] (min)	Soil Type[b]	Residual 2,3,7,8-TCDD Concentration (ppb)
429	0	A	377
430	15	A	60
429	30	A	30.8
428	90	A	10.2
429	90	B	2.86
475	0	A	67
478	15	A	8.4
477	30	A	3.7
479	30	A	3.37/3.30[c]
550	0	A	24
550	0	A	27.5
554	15	A	0.16
616	0	A	0.2
616	15	A	ND (0.08)
616	30	A	ND (0.06)
803	30	A	ND (0.02)
808	30	B	ND (0.04)
803	90	A	ND (0.08)

[a] This time begins when the target test temperature is reached; therefore, zero time is actually six to nine minutes after start of heat-up.

[b] A: Denney Farm Soil, initial TCDD Concentration of 500 ppb,
B: Reference Soil from Piazza Road initial TCDD conceration of 338 ppb.
For complete details of soil characteristics see (4).

[c] Analytical duplicate; separate aliquots of treated soil were analyzed.

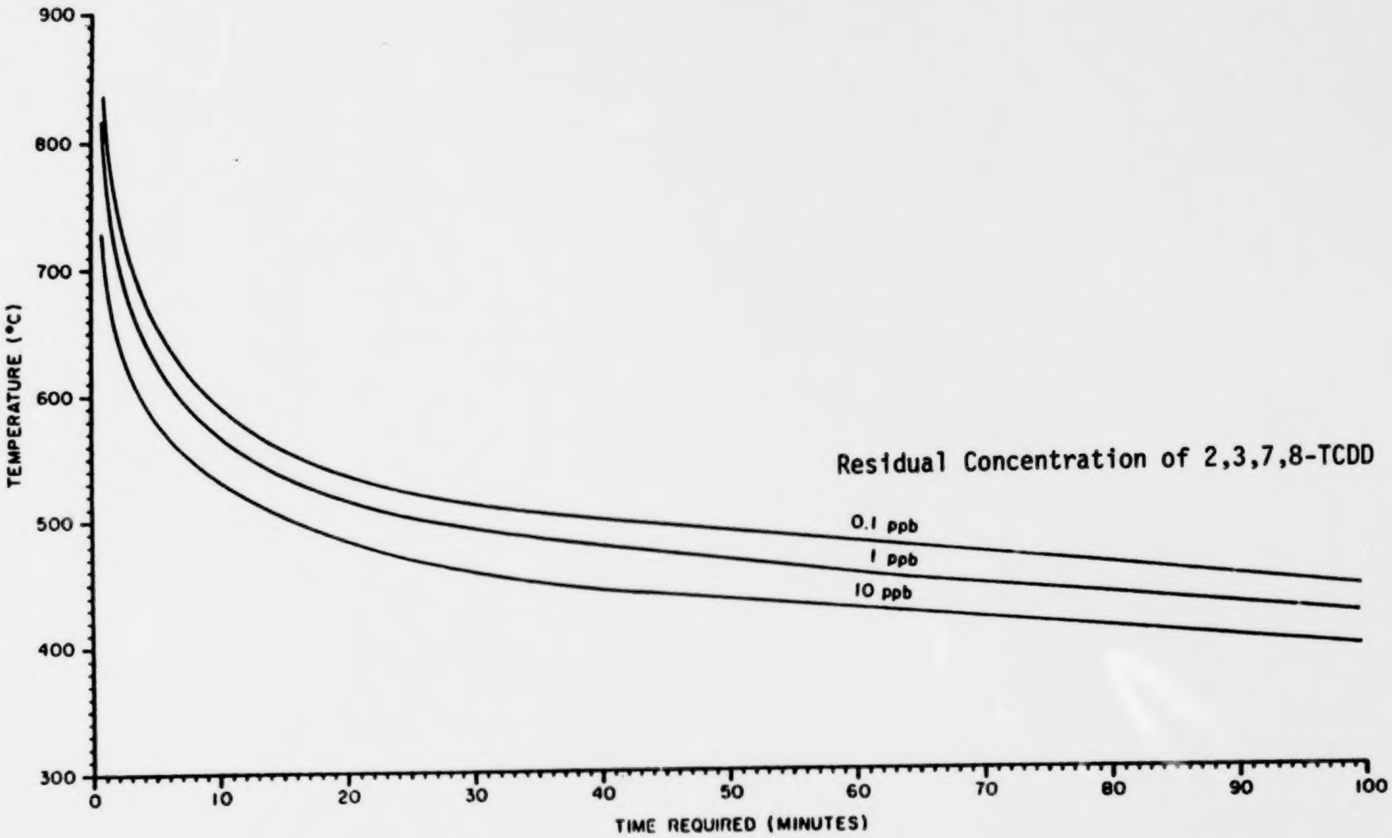


Figure 2. Effect of time and temperature on removal of 2,3,7,8-TCDD from Denney Farm soil

for Denney Farm soil initially containing over 500 ppb 2,3,7,8-TCDD would be 30 minutes at 500°C or roughly 15 minutes at 600°C.

Details of the entire laboratory study can be found in the internal EPA report entitled "Laboratory Investigation of Thermal Treatment of Soil Contamination with 2,3,7,8-TCDD" (see Annotated Index).

A pilot-scale/computer study was also conducted to define the range of the optimum solids throughput rates for the rotary kiln. Optimum solids throughput rate in this context is the maximum rate at which solids can be fed to the kiln so that the requirements for dioxin removal are met (TCDD concentration of soil exiting the kiln is less than 1 ppb) at a minimum energy expenditure per ton of soil treated.

The technical approach quantitatively defined the physical limitations of this particular kiln system to meet the time-temperature requirements for dioxin removal dictated by the results of the laboratory dioxin removal studies. The physical limitations are related to the heat transfer rate to solids in the kiln, solids flow and loading, and behavior of the soil during processing, as well as to the heat input or thermal capacity of the rotary kiln and secondary combustion system as a whole. The approach combined a number of modeling techniques. An IT Corporation in-house computer program was used to perform heat and material balance (HMB) calculations on the MIS. Then, uncontaminated soils were tested for agglomeration and slagging characteristics in a batch kiln at the Allis-Chalmers research and test center in Milwaukee, WI. Additional tests were run to determine the soil angle of repose, heat capacity, moisture content, and calcination temperature. These data were then used as inputs to a proprietary Allis-Chalmers computer program that models heat transfer in a rotary kiln. Data from the HMB program were used to select operating conditions for computer simulations in the heat transfer program. An additional program was used to calculate solids flow through the kiln.

The results of the computer programs and pilot tests allowed the calculation of the time-temperature history of soil in the kiln for different feed rates, moisture contents, firing rates, kiln excess air contents, etc. Data developed during the dioxin removal studies were then used to develop preliminary criteria for the minimum requirements for thermal treatment necessary to meet 1-ppb dioxin disposal requirements. The results of these two studies were then combined to yield estimates of the maximum solids feed rates for a matrix of soil moisture contents and kiln excess air flow rates. Recommended test conditions were selected from this matrix for use during the hot test (see below).

Shakedown in Edison, NJ

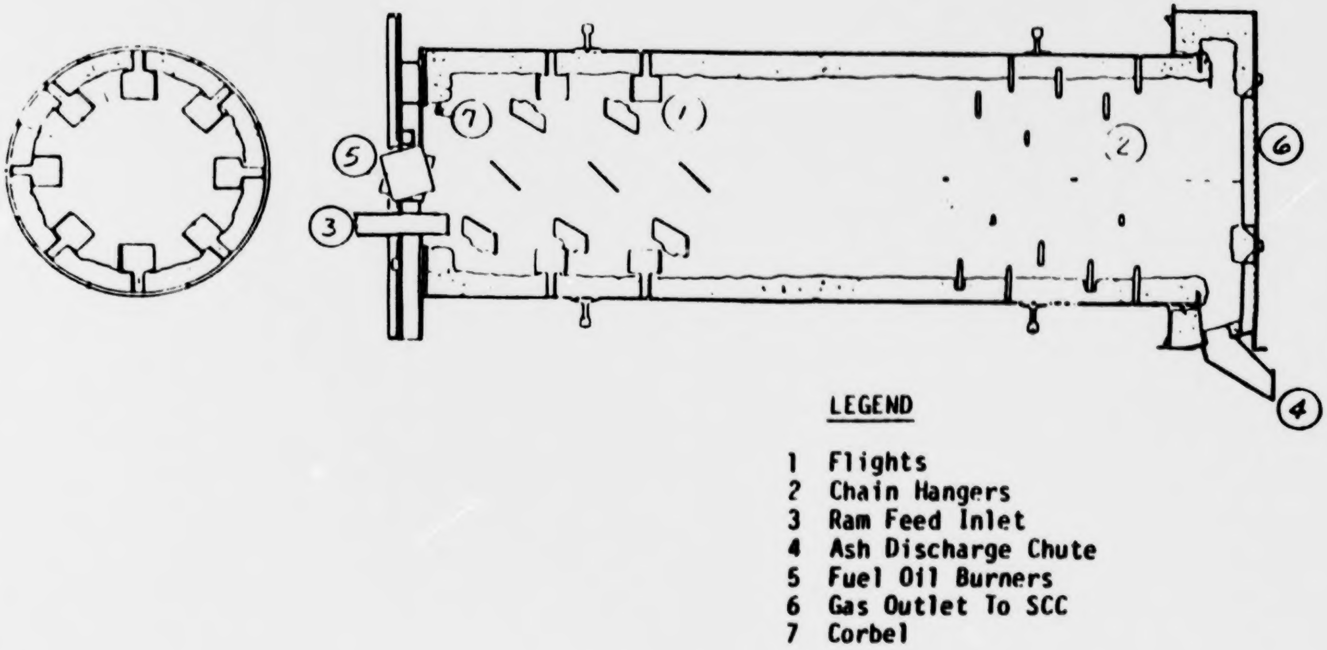
Before the Mobile Incineration System was transported to Missouri, a series of tests were conducted to ensure that the various components and the system as a whole operated properly, and to confirm that the MIS could provide the time-temperature environment needed for soils decontamination as produced by the laboratory and pilot studies. Thus, necessary modifications could be made to correct any problems discovered during the tests. The shakedown included a "cold test" and two "hot tests."

The cold test evaluated the factors that affect the retention time of solids in the kiln, including rotational speed and inclination angle of the kiln, type and rate of feed material to the kiln, and the use of flights at the inlet and heat-economizer chains at the outlet of the kiln.

The cold test demonstrated that the quantity of solids fed during a ram cycle had to be limited to prevent some of the solids from falling back behind the corbel (front dam used to retain solids in the kiln, see Figure 3) and eventually passing through the kiln front air seal. To minimize this problem, the corbel shape was changed to eliminate a "shelf" that held solids, additional flights were added to the first row to quickly advance solids away from the front of the kiln, and the ram discharge was extended further into the kiln. The number of flights in the remaining rows was reduced to enhance the solids retention time, and the kiln rotational drive gear ratio was reduced to control the rotation rate to approximately 1 rpm. Tests with chains added to the outlet of the kiln showed that the chains had minimal impact on the solids retention time in the kiln.

In addition to checking out the system at operating temperatures, IT conducted hot tests to: 1) obtain and assess data on the kiln's ability to heat soils; 2) determine the physical characteristics of the soils as they are being processed; 3) make recommendations for kiln operating conditions during the Missouri tests, using data from the hot tests; and 4) measure particulate emissions in the stack during the feeding of solids. Computer modelling (heat and material balances, heat transfer, solids flow) and pilot scale testing were performed in conjunction with the hot tests (Table 4).

Four different solids were fed through the incineration system during the hot test: 1) soil from the Denney Farm area in Missouri, 2) montmorillonite, 3) coral from Florida, and 4) Clarksburg (NJ) soil. Ten cubic yards of uncontaminated clay soil were shipped to Edison from southwestern Missouri to ensure that there would be no unusual incineration problems with soil from that area. Since the contaminated soil at the Denney Farm was very dry from being stored in a building for several years, some of the Missouri soil was spread out under shelter for several days to dry. No significant problems were encountered when feeding either the moist or slightly dried soil. Montmorillonite was fed since it will be used as the solids carrier for PCBs in Test 1 of the future Solids Trial Burn, and coral was fed since a potential use of the Mobile Incineration System at that time was for the Air Force on Johnston Island. Clarksburg soil was used for most of the testing because of its availability. All of these materials passed through the solids feed system, rotary kiln, and ash discharge system without causing any apparent problems. Residence times of over 30 minutes with ash discharge temperatures of 750^{o}C were achieved for feed rates of 2000 lb/hr with a level kiln rotating at 1 rpm.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LEGEND
1 Flights
2 Chain Hangers
3 Ram Feed Inlet
4 Ash Discharge Chute
5 Fuel Oil Burners
6 Gas Outlet To SCC
7 Corbel

Figure 3. Rotary kiln design prior to modifications for Missouri project

TABLE 4. PREDICTED AND MEASURED KILN TEMPERATURES
DURING HOT TEST RUNS[a]

Soil Type	Data[b] Source	Excess Oxygen (%)	Fuel Usage[c] (lb/hr)	Temperatures (oC)	
				Gas	Soil
Clarksburg	Hot test	3.4	137/82.8[d]	1000	800
Clarksburg	HMB	3.4	137	860	860
Clarksburg	HMB	3.4	82.8	980	980
Clarksburg	HT	3.4	82.8	910	890
Denney Farm	Hot test	3.1	158.6/67.4[d]	1000	730
Denney Farm	HMB	3.1	158.6	770	770
Denney Farm	HMB	3.1	67.4	980	980
Denney Farm[e]	HT	3.1	67.4	920	900
Denney Farm[f]	HT	3.1	67.4	930	900

[a] Clarksburg soil run beginning 9:30 a.m. November 8, 1984, and Denney Farm soil run beginning 2:10 p.m. November 8, 1984.

[b] HMB = Heat and Material Balance Program
HT = Heat Transfer Program Predictions
Hot Test = Actual Measurements

[c] Total fuel consumption per hour. Actual program runs assumed several different fuel Btu values from 18,000 to 14,200 Btu/lb.

[d] Excess air for hot test runs are reported in both percentage from recorded data and percentage calculated with the HMB program using other hot test data.

[e] Program assumes 4% loading.

[f] Program assumes 7% loading.

Stack particulate tests (EPA Method 5) were conducted to determine if feeding soils would increase particulate emissions. All previous particulate tests had been conducted while feeding liquids only. The particulate emissions measured for each of the three solid materials fed were:

Clarksburg soil	18 mg/Nm^3
Montmorillonite	17 mg/Nm^3
Missouri soil	9 mg/Nm^3

These measurements were well below the 180 mg/Nm^3, corrected to 7% O_2, RCRA particulate emission limitation.

Based on the results of the hot tests, it was concluded that the kiln capacity was limited by the solids feed system and that particulate emissions would not be a problem. The study suggested changes in operating procedures, such as operation of the kiln in a sloped position, decreasing the rotational speed, and operating with less excess air.

Upon completion of the hot tests, the kiln and SCC were opened and examined. The examination revealed that a large amount (up to 9 in) of solids had been carried over into and deposited at the front end of the SCC. Although some carryover had been expected, the quantity and location of the deposits were not. It appeared that the "spin vane," a device designed to create swirling turbulence in the gas stream and thus enhance combustion efficiency, was a major factor in the deposition of particulates at the front end of the SCC. At that time it was decided not to make any changes in the spin vane, but to carefully and frequently monitor the operations and check for solids buildup in the SCC. A number of modifications were made to correct several minor problems; a second hot test was run to ensure that these problems had been corrected. The system was then dismantled and prepared for shipment to Missouri.

OPERATING PROCEDURES AND OPERATOR TRAINING

Operating and safety procedures for the Mobile Incineration System were updated based on the new solids feed capability, the experience gained during previous operations, the special considerations required for handling dioxins, and the site-specific requirements for Missouri. The operating and safety manuals were revised to incorporate the new procedures. [See Annotated Index, Personnel Training Documents for the USEPA Mobile Incinerator System at the Denney Farm Site for an outline of the safety and training program.] All operators and other key personnel went through an extensive training course that included system operation, operating safety, and other site safety procedures. New operating data sheets were prepared; existing data sheets were modified not only to include the solids feed parameters but also to be in a format more easily followed by the operators collecting the data. New data sheets were developed to include support equipment, site inspections, waste generation, and other parameters not in the general operating logs. In addition, computer programs were developed that could be used to store and manipulate the data for ease and speed of calculating various operating conditions. Spreadsheets in Lotus were used along with IBM PC computers. The programs were set up so that a clerk could enter the data daily while in the field.

An industrial hygienist was onsite during the Dioxin Trial Burn and Field Demonstration to observe and correct operating and sampling practices, conduct personnel monitoring, make daily site safety inspections, and maintain an inventory of protective and emergency equipment. Four months into the Field Demonstration, the industrial hygienist was replaced with a safety specialist who continued the site safety program initiated by the industrial hygienist. All site subcontractors, government observers, and visitors to the site for any length of time were given site-specific safety briefings.

SITE PREPARATION AND LOGISTICS

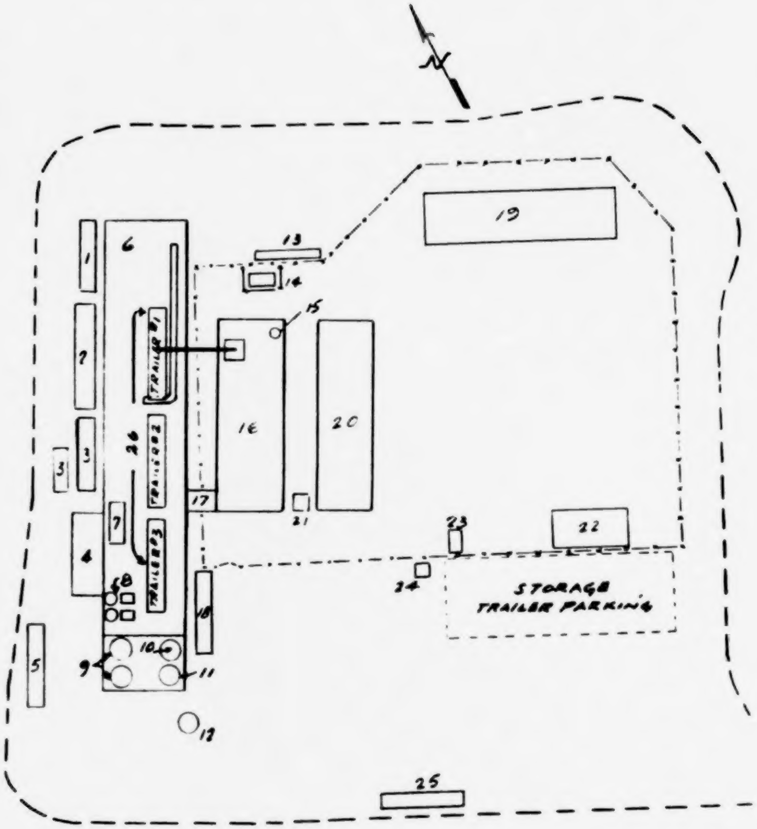
Site Planning and Preparations

Upon selection by EPA Region VII of the specific site for the MIS demonstration, detailed engineering and design commenced. The site design had to satisfy geographical, operating, and permitting requirements. The modifications were planned concurrently with the permitting activities, and the actual site construction began shortly after the RCRA and MDNR permits were received (November 1984).

To establish geographical requirements, a site survey was conducted in August 1984. Of particular interest were grades, elevations, property boundary lines, access, and existing road conditions. Figure 4 shows the site layout. Maximum consideration in the survey was given to leaving untouched, to the greatest extent possible, the natural contours, vegetation, and woodlands. The survey determined that a portion of the existing Syntex security fence would have to be moved to allow for tractor-trailer clearance in the northeast area of the site. The incinerator pad grade elevation was revised to eliminate the need for importing clean fill. This required fabrication of a feed conveyor chute extension, a relatively small cost item compared to hauling fill to the site.

The physical dimensions of the solids feed handling system and the location of the contaminated materials in the Drum Storage Building fixed the relative location of the incinerator. The goal was to maintain the incinerator in a "clean area" and prevent any increase in the contaminated area. All equipment was placed on a 4-in-thick, poured concrete pad surrounded by a 6-in-high concrete dike to facilitate containment and clean-up in the event of a spill or leakage of contaminated material in the incinerator area.

The remote, undeveloped nature of the site necessitated installation of a deep well and water supply system required for operations. Fuel oil, propane, water, and wastewater tanks were installed to accomodate the incineration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TRAILER #1
TRAILER #2
TRAILER #3
STORAGE
TRAILER PARKING

LEGEND

SYM.	DESCRIPTION
1	Office trailer
2	Operations trailer
3	Sampling and Analytical trailers
4	Utility equipment and storage area
5	Spare parts and storage trailer
6	Mobile incinerator building
7	Stack monitoring trailer
8	2 Clarifier tanks with filtration skids
9	2 15,000-Gal wastewater storage tanks
10	7,500-Gal process water storage tank
11	7,500-Gal alkaline storage tank
12	11,000-Gal fuel oil storage tank
13	HEPA filter
14	Hydraulic skid for shredder
15	1,000-Gal waste oil feed tank
16	Drum storage building (Syntex)
17	Personnel decon. station
18	Operating and Sampling crew change trailer
19	Microbiological degradation building No. 2 (Syntex)
20	Microbiological degradation building No. 1 (Syntex)
21	Water heater shed (Syntex)
22	Equipment decon. building (Syntex)
23	Personnel decon. shed (Syntex)
24	Guard shed (Syntex)
25	EPA conference trailer
26	Mobile Incineration System

Figure 4. Site layout for MIS at Denney Farm

system. Rented office and storage trailers were used extensively to minimize the construction of fixed structures. The MIS was enclosed in a 40 ft by 225 ft prefabricated shed building to protect personnel and equipment from the weather.

A guard service company was contracted to provide site security for equipment when the site was unattended and to control access of personnel during operations; a log was kept of all persons who entered and left the site. Six underground telephone lines were installed, with telephones located throughout the site. For backup emergency communications, two FM radio base stations that operated on the Monett, MO, Police Department frequency were installed.

Critical Spares

The MIS is composed of many complex instruments and pieces of equipment, many of which are difficult to obtain. The failure of a minor component can shut down the entire operation since little redundancy is built into the system. To minimize the downtime due to component failure, the critical spare components were identified. The components were evaluated with regard to their cost, expected reliability and useful life, their importance to the operation, and the time needed to replace each one. An inventory of spare parts was purchased and stocked with the incinerator; records were kept of the suppliers and of the availability for all components.

Transportation and Setup of Incinerator

The MIS was transported to and set up on the Denney Farm site in mid-December, 1984, after site modifications were essentially complete. In addition to the four main trailers of the incineration system, five additional trailers were required, including a personnel decontamination trailer, and trailers to transport auxiliary equipment and spare parts. Inclement weather delayed the site preparation work during November and December 1984, particularly the completion of the incinerator building and the site grading. To keep the project moving, the incinerator was set up while the site work was progressing, but the two operations frequently conflicted, thereby creating personnel and management problems.

Additional support equipment was provided by Syntex, purchased, or leased to complete the incineration system setup. Syntex provided four storage tanks ranging from 10,000-gal to 15,000-gal capacity to be used for makeup water, alkaline solution, and wastewater storage. Seven trailers were leased to provide lunch and rest space for the operators, office space for EPA and operating management, work space for sampling and analytical personnel, work space for EPA observers and public information personnel, and shelter for the site guard service. Other leased auxiliary equipment included such items as forklifts, a backhoe, power generators, air compressors, storage vans, and space heaters. Fuel oil and propane storage tanks were furnished by local suppliers.

FIELD SHAKEDOWN AND PRELIMINARY TESTING

Final preparations, component checks, and on-site personnel safety training were completed in early January 1985 and the incineration system was started with fuel oil on January 14 to check out its performance after its move from New Jersey. The startup proceeded smoothly and the system was brought to operating temperature within two days; however, the solids feed shredder apparently jammed with clean Missouri soil shortly after it was started during subfreezing temperatures. The frozen soil was removed from the shredder, but the problem was eventually determined to be a broken drive spline in the shredder drive motor. This was probably caused by a combination of the high viscosity of the hydraulic drive fluid and differential contraction of internal motor components, both attributed to startups during subfreezing temperatures.

Extremely cold weather (-15°F, -50°F wind chill) that lasted for several days caused frozen water lines and gelled fuel oil so that the operating crew spent most of its time struggling to keep the system operating. In addition, a leased air compressor with only 100 hours of operation on its hourmeter malfunctioned and discharged lubricating oil into the instrument air system, creating problems with the continuous monitoring system. Because of the oil in the air lines, the broken solids shredder, and several other minor problems, the system was shut down nine days after it was started, the operating crew returned to New Jersey, and a repair crew undertook repairs.

The vendor repaired the shredder and it was reinstalled and tested without soil. The air compressor was replaced with a heavy-duty, oversized unit, the air lines were cleaned of oil, and other maintenance was performed. The incineration system was restarted February 9, 1985, but a number of problems hampered initiation of the trial burns. Both the main power generator and its backup malfunctioned and a third unit had to be leased and brought to the site. The shredder drive spline broke again when solids were fed to the shredder, even though the hydraulic oil line was heat traced and covered. Apparently, debris left in the hydraulic fluid from the previous failure combined with subfreezing temperatures caused the break. The hydraulic fluid was completely flushed and changed and the spline was replaced on site. The shredder subsequently performed well, until a similar failure occurred during the Field Demonstration.

As part of the startup plan, a blend of 15% by volume sodium sulfate and clean local soil was fed to the incinerator to evaluate whether the salt would cause slagging and ash removal problems in the rotary kiln. The test was conducted because of the need to incinerate 23 cu yd of dioxin-contaminated sodium sulfate at the Syntex Verona, MO, plant. The sodium sulfate/soil feed caused severe jamming problems with the ram and other parts of the solids feed system. The soil was basically a wet clay that became almost brick-like when compacted with the salt. Since dry soil, other than that contaminated with dioxin, was unavailable due to the heavy rains, gravel was fed to the incinerator while subsystems were being checked in preparation for the trial burns. It was determined that the salt would have to be fed at much lower concentrations, if at all, in order to minimize the operating problems.

Preparations were made to conduct Test 1 of the Trial Burn (see Trial Burn Plan, below), and the tetrachloromethane/methanol liquid blend and PCB/hexachloroethane/montmorillonite solids blend were fed to the incinerator. However, before the system could be brought to equilibrium for the sampling to start, a number of problems developed, primarily in the quench system of the air pollution control section. The quench pump (used to recycle water from the quench sump to the quench sprays) lost suction head. As a result, the recycle flow rate dropped to a level below the interlock set point, which automatically shut down the entire incineration system. The problem was eventually traced to a cracked seal in the pump suction piping that allowed air to enter and caused the pump to lose suction.

After the quench pump was repaired, high volumes of tetrachloromethane/methanol were fed to the incinerator to verify that the air pollution control system was functioning properly. During this time, gravel was fed to demonstrate that the entire incineration system was reliable enough to attempt a trial burn. However, the gravel was actually limestone, which created such a fine dust when it was heated in the kiln that a substantial portion became entrained in the gas stream, passed through the SCC, and collected in the quench sump, again creating quench sump suction problems. This problem was solved by switching the solids feed to river rock and installing a hydrocyclone on the quench sump to remove suspended solids. The hydrocyclone system was very successful in keeping the quench sump liquor free of accumulated solids.

Preliminary stack particulate testing with a high feed rate of chlorine (equal to that scheduled for Test 1) revealed corrosion problems with the carbon-steel sound attenuator stack section, causing fine particles to be emitted from the stack, in excess of RCRA particulate standards as determined by a preliminary stack sampling test. The attenuator was replaced by a stainless steel stack section.

After consultation with Region VII management and incinerator operating personnel, HWERL decided to defer the high-chlorine Test 1 and conduct the Dioxin Trial Burn (Test 2) first. Dioxin-contaminated liquids and solids were fed to the incinerator for the first time on February 26, 1985. Problems delayed the test run almost immediately, when the liquid feed line, which had been used thus far without difficulty, developed a small leak, probably the reult of a change in the viscosity of the feed liquids. A minor spill of dioxin-contaminated material resulted. This spill (several ml) was cleaned up in accordance with the site safety protocol, and the leak was repaired. The system was brought back to equilibrium, the feeds were restarted, and the first trial burn run began. However, when the run was about 25% complete, the drive belt between the diesel engine and the induced-draft fan broke and the loss of vacuum caused the entire incineration system to shut down. Replacing the belt and restarting the system required several hours, so the run was aborted. The next run was scheduled for early the following morning (February 28) and was conducted with few problems. It was the first completed dioxin trial burn run.

Entrained solids carryover from the kiln became a problem because of accumulation in the secondary combustion chamber in front of the lower of the two fuel oil burners. The mass of solids became a glass-like slag that interfered with the burner operation. The burner was removed each night and the solids that could be reached were removed manually by chipping with a sledgehammer and a steel pipe. When the burner was removed after the completed test run, a large hole was discovered in the internal spin vane that introduces swirling turbulence to the gases that enter the SCC. The Inconel (a high-temperature nickel alloy) vane evidently melted when the slag buildup deflected the burner flame onto the vane. Because the vane was a critical component, the system was shut down and the operating crew sent home on March 2, 1985.

A plan was developed in consultation with incineration experts in March 1985 to rebuild the spin vane, make minor operating adjustments, and continue with the Dioxin Trial Burn while carefully observing the solids buildup in the SCC. The plan also called for more extensive modifications to be made during the shutdown period after the Trial Burn and before the Field Demonstration.

The SCC was completely cleaned, the new spin vane was fabricated and installed, and routine maintenance was performed during March. The incinerator was restarted April 1, and three more dioxin trial burn test runs were executed over four days.

The Syntex lagoon sludge evaluation, Test 3, was conducted after the dioxin test was completed. The sludge was the first combustible solid fed to the Mobile Incineration System. The test went well, but when the SCC was checked after the test, a large amount of solid material was observed near the spin vane.

Because of the solids buildup and concerns regarding the reliability of the polarographic oxygen analyzer of the stack monitoring system, the incinerator was shut down on April 11 before Test 1 was conducted. In the months that followed, modifications were made to alleviate the solids buildup problem and some of the other problems identified during the three operational periods. One of the major modifications involved the design, fabrication and installation of a "drop-out box," a 6-ft-long section added to the front end of the SCC to catch and accumulate the solids carried into the SCC and that were being trapped by the effect of the spin vane on the gas flow pattern.

Another modification involved the changing (from Maxon to North American) and repositioning of the burners (rotating them 22.5^{0} around the longitudinal axis) in the SCC to facilitate burner maintenance and to avoid the earlier problem of flame impingement onto the spin vane. The repositioning of the burners helped protect the spin vane, and in addition, the new position encouraged more swirling turbulence of the gases in the SCC. These modifications improved the on-stream factor of the incinerator from 30% to 50%.

A filter skid was added to the MX scrubber sump. This allowed more efficient operation of the sump. The MX scrubber liquid was recirculated and the fine particles were filtered out. A more detailed description of the modifications made to the Mobile Incineration System between the end of the trial burn and the beginning of the field demonstration can be found in the report entitled USEPA Mobile Incineration System Particulate Drop-Out Feasibility Study (see Annotated Index).

Unanticipated Problems

Many of the problems experienced in January and February were caused by the weather, rented support equipment, and requirements for redundant, reliable subsystems. Other problems were caused by premature failure of normally reliable components, like fan belts. However, there were several problems specific to incineration of certain types of feeds, such as effervescence in the quench sump, corrosion in the stack, and the particulate carryover. Extensive shakedown operations on the exact materials to be treated appears to be the only effective way to uncover and rectify such problems, but regulatory constraints (RCRA, TSCA) and public concerns had necessitated that the shakedown at Edison be conducted with surrogate soils, and the problems specific to the feed types were not discovered until field operations began. It should be noted, however, that these problems relate to the operation of the incineration equipment and not to the primary regulatory performance criteria, i.e., DRE, HCl removal, particulate emissions, etc.

Morale, a critical factor in an isolated operation such as this, was seriously affected by the equipment and operating problems and the sulifreezing weather. When the ground thawed, the site received 3.5 inches of rain which turned the access road into a quagmire passable only by four-wheel-drive vehicles and heavy duty trucks. This problem not only affected morale by limiting the crew's personal time by delaying shift changes, but also threatened the continued operation of the system when replacement parts and fuel could not be delivered. Repairs to the road required more than a week and several hundred tons of rock, a considerable unanticipated expense.

These problems emphasize the risks if the site is not prepared to anticipate the worst possible local weather conditions. The costs in lost operating time due to site inaccessibility can be avoided by sufficient planning. Conversely, excessive preparation efforts may not be justified. However, a thorough incineration system shakedown and a complete inventory of working spare parts are absolutely necessary.

PLANNING AND EXECUTION OF A RCRA/TSCA/DIOXINS TRIAL BURN

Trial Burn Plan

The purpose of the Trial Burn was to obtain data, which, when combined with data previously obtained from the Liquid Trial Burn in Edison, NJ, would verify that 1) dioxins and other hazardous organic liquid and solid materials are adequately destroyed by incineration in the EPA Mobile Incineration System, 2) the resulting stack emissions do not pose an unacceptable health or safety risk to the surrounding communities, and 3) the byproducts, including processed soils and cooling water, pose no unacceptable health risk and can be delisted from the RCRA hazardous waste list. The Trial Burn was designed to provide data to support the issuance of the State and Federal permits required for use of the incinerator at the Denney Farm site in southwestern Missouri. The tests, as configured in this Plan, are intended also to provide sufficient data which, when combined with the data from the Liquid Trial Burn, will enable future use of the EPA Mobile Incineration System on practically any hazardous organic material at Superfund and other hazardous waste sites.

At the Denney Farm site and at other locations in Missouri, dioxins, PCBs, and RCRA-regulated substances are stored or exist as liquids and solids. Therefore, trial burn data on these materials in both liquid and solid form are necessary for evaluating the performance of the MIS. EPA and State regulatory offices currently require trial burn data on both liquids and solids because of the processing differences between liquids and solids in the kiln of a kiln-plus-secondary-combustion-chamber-type incinerator. In part, this is because organic liquids can be passed through a burner flame and directly oxidized, whereas solids are heated more slowly by thermal radiation, by contact with hot gases, and by contact with refractory in a kiln. Further, because of the public sensitivity of dioxins, a special dioxin trial burn -- as applied to contaminated liquids and solids -- was requested by the EPA Dioxin Disposal Advisory Group and the Office of Solid Waste in support of the development of RCRA regulations.

The Trial Burn program was planned to consist of three tests. Each test was to consist of three replicate sampling runs, i.e., a total of nine sampling periods. However, due to operational problems that arose during the Trial Burn (see above), Test 1 was not executed. Test 1 will probably be executed at the end of the Field Demonstration and the results reported later. The Trial Burn Plan was extensively reviewed by scientific and regulatory reviewers, and formed a major portion of the RCRA/MDNR permit application.

1. Test 1

   During Test 1, a PCB matrix (prepared by spraying 8.5 wt % Askarel oil containing 50-65 wt % PCBs onto 86.5 wt % montmorillonite) mixed with hexachloroethane to achieve a 5% feed concentration will be fed to the rotary kiln. In addition, two liquid streams will be fed to the rotary kiln, one an organic liquid having a low heat value consisting of tetrachloromethane and methanol, and the other an aqueous stream containing a portion of the organic liquid. The objective of this test will be to obtain for the Mobile Incineration System: 1) a TSCA non-liquid PCB permit, 2) a RCRA non-liquid permit, and 3) a RCRA liquids permit that will allow the incineration of organic liquids and contaminated aqueous liquids (no contaminated water was previously tested during the Liquid Trial Burn). This test will consist of three runs of 8-12 hr each to collect the required three replicates of 4 m^3 of stack gas sample.

2. Test 2

   During this test, 2,3,7,8-TCDD-contaminated soil and dioxin-containing waste liquids were fed to the rotary kiln. The purpose of this test was to demonstrate the Mobile Incineration System's ability to destroy dioxin at the 99.9999% DRE level and to obtain delisting data on byproduct solid and liquid. This test consisted of four successful runs; each 8-12 hr run was used to collect the required 4 m^3 of stack gas sample.

3. Test 3

   Bromine-contaminated sludge was fed to the rotary kiln. The purpose of this test was to demonstrate the Mobile Incineration System's capabilities for control of bromine/hydrogen bromide emissions while incinerating bromine-contaminated wastes. The test consisted of three runs of 0.5 hr each.

Quality Assurance Project Plan

Preparation activities for the Trial Burn included formalized detailed planning required of all EPA-sponsored research programs, namely the preparation of a Quality Assurance Project Plan (QAPP). The QAPP was prepared to the highest practical standards for the project and focused on the details of collecting, handling, and reporting the Trial Burn data and results and established quality criteria for all data to ensure that the Trial Burn data would be technically sound and acceptable to regulatory agencies. This document underwent extensive review by technical experts, both inside and outside of the Agency, and regulatory officials. The QAPP encompassed two separate aspects of the Trial Burn: the operation of incineration equipment and the collection of routine operating data. The plan also described in great detail the collection and analysis of special samples associated with the Trial Burn.

Information from the routine operation of the MIS is of special interest to regulatory officials. The incinerator operating conditions and the requirements for data collection and reporting are defined in State and Federal regulations and are specific terms of the Trial Burn and subsequent operating permits. The QAPP addressed these requirements by detailing operating conditions, defining the conditions under which testing can be initiated or halted, identifying the calibration criteria for important instruments such as the continuous emission monitoring system, specifying data to be collected, and describing how the data quality will be determined and maintained. The operating data from the Trial Burn were used in conjunction with incinerator performance results to define normal operating conditions during the Field Demonstration.

The QAPP also described the collection and reporting of information to determine incinerator performance during the Trial Burn. In order to ensure the accurate measurement of incineration performance, an extensive sampling and analysis (S/A) plan was developed. This plan described the exact procedures to collect representative samples of all feed and effluent streams. The sampling techniques range from the very simple, e.g., collecting waste water samples for standard analyses, to the very complex, e.g., collecting stack gas samples for measurement of nanogram quantities of 2,3,7,8-TCDD. The S/A plan also provides all the specific procedures for sample analyses. Standard analytical protocols were used whenever possible, but the determination of 2,3,7,8-TCDD in incinerator emissions and byproducts requires state-of-the-art analyses to demonstrate the required DRE. The samples were analyzed by two laboratories to provide independent verification of test results; all samples were analyzed at the primary laboratory, IT Analytical Services in Knoxville, TN, and selected samples were also analyzed by EPA Region VII laboratories and their contractor, Midwest Research Institute, for critical dioxin results. Detailed QA/QC data were sent to the EPA Environmental Monitoring and Support Laboratory in Las Vegas and to Region VII for review.

As part of the operating plan, 2,3,7,8-TCDD was the compound of primary interest, with supplemental analyses of tetra-, penta-, hexa-, and octa-cogeners of dioxins and furans as products of incomplete combustion.

Dioxin Trial Burn Results

The feed materials for the Trial Burn consisted of dioxin-contaminated liquid still bottoms and soil for Test 2, and dioxin-contaminated lagoon sediment for Test 3. The still bottoms, taken from a trichlorophenol purification still, were blended with solvents to maintain the 2,3,7,8-TCDD concentration within permissible limits. They were analyzed prior to the Trial Burn to verify the 2,3,7,8-TCDD concentration and to select an appropriate liquid waste feed rate. The blend was prepared by mixing 500 gal of waste oil with 55 gal of methylene chloride and 275 gal of butanol. The dioxin-contaminated soil came from the original Denney Farm trench and had been kept in a covered concrete basin as loose soil. The soil was placed in 55-gallon drums which were subsequently emptied into the solids feed system. The lagoon sediment, taken from an industrial waste storage lagoon in Springfield, MO, contained 2.8% brominated naphthalenes and 1-21 ppb 2,3,7,8-TCDD. This material was stabilized with calcium oxide and was transferred to the Denney Farm site in 55-gallon drums for processing.

The incinerator operating conditions used during the Dioxin Trial Burn were essentially the same conditions that were used during the previous Liquid Trial Burn successfully conducted in New Jersey. Waste liquids and solids were fed to the rotary kiln. The solids were retained in the rotary kiln, which was operating at 1550-1750°F, for approximately 30 minutes before being discharged into drums. The gases from the waste combustion flowed into the secondary combustion chamber where they were heated to 2100-2250°F. In each chamber, the combustion gases were mixed with excess oxygen (air), and were retained for sufficient time (estimated at 1-3 sec in the kiln and 2.4-3.0 sec in the SCC) to completely oxidize the organic waste constituents. The combustion gases then passed through three stages of air pollution control equipment to cool and filter particulate matter (primarily from the solid wastes processed), and neutralize the acid component of the gases. Other process byproduct effluent streams (kiln ash, CHEAF media, and purge water) were collected and analyzed in accordance with delisting guidelines and the Trial Burn Plan to determine if any of the predesignated hazardous materials were discharged from the incineration system.

During the Trial Burn, approximately 1750 gal of trichlorophenol still bottoms (mixed with hexane and butanol) containing an average of 250-350 ppb 2,3,7,8-TCDD and over 80,000 lb soil containing 100-900 ppb 2,3,7,8-TCDD were incinerated. The total dioxin destroyed during these tests was calculated at 3.84 lb.

The performance of the incinerator during the Trial Burn was determined by monitoring all feed and effluent streams. The performance criteria for Test 2 were the destruction and removal efficiency (DRE) for 2,3,7,8-TCDD and the particulate emission rate (Table 5 and Appendix A). Control of bromine emissions was monitored during Test 3. The test results show that the incinerator continues to provide satisfactory performance in destroying organic waste materials, and this ability has now been demonstrated on both solid and liquid waste materials. In fact, the incinerator's performance is actually better than that reported since the actual emissions are lower than what is measurable by the sampling and analytical technology used. No 2,3,7,8-TCDD was detected in the stack, using state-of-the-art sample clean up methods and high-resolution mass spectrometry. The lowest DRE for 2,3,7,8-TCDD was 99.999973%. The best DRE measured during the Trial Burn occurred in Test 2-4 which had the lowest analytical sensitivity (Table 5). The DRE for this run was 99.999995%, fifteen times better than State and Federal requirements. Although the spin vane probably failed prior to Test 2-2, the results are still very encouraging.

Some problems were encountered with the measured levels of particulates in the stack, with one run of four being somewhat in excess of the RCRA standard of 180 mg/Nm^3 (@ 7% O_2). This was attributed to a buildup of fine particles in the mass transfer scrubber liquor and subsequent entrainment of that liquor in the stack gas. For the Field Demonstration, a 50-u cartridge filter system was installed in the water recycle system for the mass transfer scrubber. Additional stack testing done 14 days after the start of the Field Demonstration confirmed system performance, indicating that particulate emission levels were 90-130 mg/Nm^3 (@ 7% O_2), well below the RCRA standard. The CO emission values are equivalent to those from the best available incineration technologies and are indicative of very complete combustion.

HCl data for permit purposes were provided from the previous Liquid Trial Burn in New Jersey; no HCl measurements were taken during the Dioxin Trial Burn.

The results of Test 3 were also satisfactory in that no bromine or chlorine was detected in the stack gas.

Quality Assurance/Quality Control

The MIS trial burn had a well-defined quality assurance/quality control (QA/QC) program to ensure the collection of accurate data. This program was developed as part of the preparation activities and was formalized in the Quality Assurance Project Plan (QAPP) dated December 6, 1984. The QAPP defined the procedures to fulfill the requirements of the EPA-HWERL 15-point guideline for collecting important research data and to demonstrate compliance with State and Federal regulations. The QAPP was reviewed and approved by EPA quality assurance officials. The quality assurance activities were divided into two areas: 1) operating and combustion parameters and 2) sampling and analytical parameters.

Operating and combustion parameters were determined from readings taken from incinerator monitoring instruments and continuous emission monitors. In general, these parameters were measured during both the trial burn and routine system operations. The major lessons that were learned during the operations in Missouri include:

- Setting realistic quality assurance completeness, precision, and accuracy goals; and
- Providing independent checks on the measurement of process variables.

TABLE 5. RESULTS OF MISSOURI TRIAL BURN

Parameter	Permit Limit	Test Number 2-2[a]	2-3	2-4	2-5	3-1,2,3[b]
Kiln						
Temp. (°C)	760/1040	900	870	910	940	860
SCC						
Temp. (°C)	1120/1315	1190	1200	1200	1200	1190
O_2 (Vol %)	4	7.7	7.0	6.4	6.4	7.6
CO (Vol ppm)	100	4.1	2.0	2.3	2.5	3.5
Retention Time (sec)		2.5	3.2	2.5	2.6	d
Halogen Removal Efficiency	>99	e	e	e	e	99.0
DRE (%)						
2,3,7,8-TCDD[c]	>99.9999	>99.99997	>99.99998	>99.99999	>99.99998	e
Particulate Emission Rate (mg/Nm^3 @7% O_2)	<180	134	147	146	202	e

[a] Test 2 liquid feed - TCDD-contaminated trichlorophenol still bottoms (with methylene chloride and butanol solvents)
solid feed - TCDD/trichlorophenol-contaminated soil

[b] Test 3 liquid feed - fuel oil
solid feed - TCDD/brominated naphthalene-contaminated lagoon sludge
Combined results for three 0.5 hr runs

[c] 2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin

[d] Not calculated

QA/QC Goals--

Parameter measurements defined in the QAPP as quality assurance goals specified precision, accuracy, and completeness objectives for measurements of operating parameters specified in the operating permits. The goals were established using previous trial burn data and manufacturers' specifications for the monitoring and analytical instruments.

QA goals in the QAPP established acceptance criteria for key operating data set for measurements of kiln and SCC temperature and combustion air rates, waste feed rates, and excess oxygen, carbon dioxide, carbon monoxide, and nitrogen oxides (Table 6). These goals pertained to the calibrations performed on the specified instruments. Most of the QA goals were met. Some of the QA parameters were not calculated because there were insufficient numbers of repeated calibration points to calculate meaningful statistics. This discrepancy was corrected during the Field Demonstration by modifying the calibration procedures for those instruments. QA goals that were not met included those for the combustion air blowers for the kiln and SCC and for selected gas components measured by the continuous emission monitors.

The combustion air flow rate measurements at the kiln exit and SCC provide data used to determine and control the total gas flow through and the oxygen concentration in each chamber. The flowmeters were calibrated according to the manufacturer's suggested procedures; they demonstrated linear response with respect to the air flow rate but they did not meet the QA goals for precision and accuracy. Evaluation of these air flow data showed that the measurements made by these meters are usable, but that the precision and accuracy of the meters are subject to drift.

The continuous emission monitors (CEMs) were calibrated daily. In general, the CEMs performed better during the Dioxin Trial Burn than during previous incinerator tests. However, the carbon monoxide (CO) calibrations during the Dioxin Trial Burn did not meet QA criteria for precision or accuracy. The QA criterion for each of these parameters was ±5% percent of the measured concentration or 5 ppm, whichever was less. The measurements made during the Trial Burn were outside this range because the CO analyzers were operated near their limit of detection. The analyzers were calibrated to maximize performance in the 0 to 10 ppm range; calibration standards at 100 ppm were too variable to satisfy the QA criteria. The trial burn test data for CO were acceptable because the calibration data in the 0-10 ppm range met the accuracy goals.

The completeness criteria describe how much of the data met the precision and accuracy goals. The calibration completeness goal for the CEMs was not met for most parameters. The reasons for not meeting the goals and recommended corrective actions are different for each CEM.

Table 6. QA Summary for Combustion and Operating Parameters

					Completeness			
	Precision (%)		Accuracy (%)		Precision (%)		Accuracy (%)	
Parameter	Goal	Actual	Goal	Actual	Goal	Actual	Goal	Actual
Kiln Temperature	5	NC	5	1.2	90	NC	90	100.0
SCC Temperature	5	NC	5	0.6	90	NC	90	100.0
Waste Oil Flow Rate	5	NC	5	3.0	90	NC	90	100.0
Waste Solids Flow Rate	10	0.0	10	0.0	90	100.0	90	100.0
Waste Aqueous Flow Rate	5	NA	5	NA	90	NA	90	NA
Kiln Combustion Air Flow Rate		NC		4.1	90	NC	90	46.7
SCC Combustion Air Flow Rate		NC		12.1	90	NC	90	17.6
Continuous Emission Monitors								
Oxygen	5	2.8	5	3.2	90	100.0	90	76.5
Carbon Dioxide	5	1.8	5	1.4	90	100.0	90	95.8
Carbon Monoxide	5	10.5	5	10.4	90	66.7	90	72.3
Nitrogen Oxides	10	9.4	10	9.2	90	66.7	90	71.9

NC - Not calculated due to insufficient repeated calibration points for meaningful statistics.

NA - Not applicable since no material fed through aqueous flow meter.

Precision expressed in terms of relative standard deviation (standard deviation/mean).
Accuracy expressed as the percentage difference from true (standard) value.
Completeness expressed as the amount of valid data obtained compared to the total amount collected.

The criteria for the oxygen system measurements were that 90% of all calibration data fall within ±5% of the actual values for both precision and accuracy. While the average precision (2.8%) and accuracy (3.2%) met these goals, 76.5% of the calibrations had errors greater than 5%. Typically, this occurred with the 3.0% certified standard. It is not clear whether the problem was caused by nonlinear performance of the analyzers or a bad calibration gas cylinder. Modifications were made on the CEMs to prevent this situation from occurring during the Field Demonstration. It is worth noting that more than 96% of the oxygen calibrations met a ±10% accuracy criteria, even when the 3.0% standard data were included.

Improvement of the linearity of the instruments improved the precision and accuracy of future calibrations. This approach was done carefully, however to preserve data quality in the normal range of CO concentration (0 to 10 ppm).

The nitrogen oxides (NO_x) analyzer did not meet calibration data completeness criteria for either precision or accuracy. The NO_x analyzer performance was erratic. Although operation improved after servicing by a manufacturer's representative, it still failed to meet the 90% data completeness goal. Evaluation of the NO_x calibrations indicated that the calibration of stream No. 1 (SCC) was more difficult than stream No. 2 (stack). The corrective actions included 1) improvements in the SCC sample probe operation to reduce the plugging problems experienced with stream No. 1 during the trial burn and 2) increased operator attention.

Acid gases in the flue gas sample stream degraded the performance of the polarographic oxygen analyzer and the non-dispersive infrared (NDIR) carbon monoxide analyzer. These constant readout analyzers were used on one of the two samples of the SCC exit gases, and were used to backup the continuous gas chromatograph (GC) analyzers on the other stream. Both the polarographic oxygen analyzer and the non-dispersive infrared (NDIR) carbon monoxide analyzer required frequent calibration.

Cross-Checking Procedures--

The QAPP for the trial burn also included cross checks of selected instruments to independently assess data accuracy. For example, a liquid waste flow rate check was made by measuring the volumetric change in liquid level in the waste feed tank. The volumetric change was converted to a weight/time flow rate using the liquid density and elapsed time. This rate was then compared to the feed rate measured by the liquid waste flow meter. During Tests 2-1 and 2-2 there were acceptable agreements (9.3% difference) between the two flow measurements. During Test 2-3 there were problems determining the liquid level in the waste feed tank because of liquid color and the presence of suspended solids in the tank sight glass. This was corrected by using a dipstick to determine the change in liquid level; the difference in the flow measurements was only 4.5% by this method.

In summary, a number of QA criteria were relatively stringent and would be difficult for a permanent facility to meet.

PLANNING AND EXECUTION OF A FIELD DEMONSTRATION

A number of activities remain to be completed as of June 1986, including the Field Demonstration and Test 1 of the Trial Burn, which will occur after Superfund is reauthorized and operating funds are made available for the project.

Field Demonstration

The objective of the Field Demonstration was to determine the rates at which various dioxin-contaminated liquids and solids could be fed into the system and decontaminated. In addition to evaluating the capability of the MIS, the demonstration will result in the cleanup of the majority of dioxin-contaminated material in southwestern Missouri. The specific materials that were incinerated are listed in Table 7.

The Field Demonstration started on July 23, 1985 and ran to February 6, 1986. IT Corporation operated the MIS until August 27, 1985, after which operations were taken over by Enviresponse, Inc. (EI), a subsidiary of Foster-Wheeler Corporation. Operations were suspended during September 1985 to October 3, 1985 for administrative reasons, and again during the 1985 Christmas holidays. Otherwise, operations were continuous at 24 hours per day, 7 days per week.

When activity was suspended and the feed discontinued on February 6, 1986, 2 million pounds of solid wastes and 180,000 pounds of liquid wastes had been incinerated. Of this, 1.5 million pounds of solid waste were incinerated under EI management in 116 operating days, and 107,000 pounds of liquid waste were incinerated under EI management in 80 operating days (no liquids were incinerated during the first 36 days of operation). This resulted in a daily average of 12,892 pounds of solids and 1,343 pounds of liquids incinerated.

The byproduct ash, CHEAF media, and process water were delisted under guidelines issued by the USEPA Office of Solid Waste, in cooperation with the Missouri Department of Natural Resources. The guidelines were published in the Federal Register (8) and included testing each tank of process water for mercury, selenium, and chromium, and daily composite samples of ash and CHEAF media for mercury and selenium. Table 8 shows some representative delisting data and the limits set forth in the Federal Register exclusion notice. Byproduct ash and CHEAF media were sent to a local municipal landfill for disposal. Water was land-applied.

TABLE 7. FEED MATERIAL FOR FIELD DEMONSTRATION

Material	Estimated Quantity	2,3,7,8-TCDD Conc. (values variable)
Denney Farm		
MDB Soil	210 cu yd	100-900 ppb
Mixed solvents and water	2590 gal	Low
Chemical solids and soils	31,150 lb	1 ppb - 2 ppm
Drum remnants and trash	84 85-gal overpack drums	Unknown
Verona		
Hexane/Isopropanol	7,000 gal	0.2 ppm
Extracted still bottoms	3,500 gal	0.2 ppm
Sodium sulfate salt cake	23 cu yd	1 ppb
Miscellaneous trash	1,200 lb	Unknown
Neosho		
Spill area soil	654,000 lb	50 ppb
Bunker soil/residue	7,500 lb	2 ppm
Erwin Farm		
Drums of solid	796,000 lb	8 ppb
Drums of liquid	8,000 lb	8 ppb
Rusha Farm		
Spill area soil solids	63,000 lb	50 ppb
Spill area soil liquids	500 lb	Unknown
Talley Farm		
Spill area soil solids	357,000 lb	6 ppb
Spill area soil liquids	3,000 lb	6 ppb
Eastern Missouri		
Times Beach soil sample	3 cu yd	500 ppb
Piazza Road soil sample	3 cu yd	1600 ppb

TABLE 8. REPRESENTATIVE DELISTING DATA*

Sample No./Type	Date	Concentration of metal Cr (ppb)	Hg(ppb)	Se (ppb)
X3003/Water	8/21/85	221	5	26.59
X2978/Water	8/19/85	232	5	20.19
X2936/Water	8/18/85	323	5	26.14
X2902/Water	8/15/85	510	5	12.04
X2906/Water	8/15/85	858	5	52.01
X2908/Water	8/15/85	149	5	8.64
X2883/Water	8/13/85	505	5	32.15
X2976/CHEAF	8/8/85	---	5	428.64
X2975/CHEAF	8/7/85	---	5	17.84
X2974/CHEAF	8/5/85	---	17.21	18.15
X2835/CHEAF	8/1/85	---	5	5
J1497/CHEAF	7/24/85	---	5	55.63
J1484/CHEAF	7/23/85	---	17.34	202.17
X2939/Ash	8/18/85	---	5	48.48
X2979/Ash	8/18/85	---	5	40.15
X2934/Ash	8/18/85	---	5	35.30
J2876/Ash	8/16/85	---	5	24.37
J2875/Ash	8/16/85	---	5	15.33
J1498/Ash	8/16/85	---	5	26.45
J1441/Ash	8/15/85	---	5	100.12

*Delisting limits: Water: Cr = 680 ppb, Hg = 30 ppb, Se = 140 ppb
Ash/CHEAF: Hg = 44 ppb, Se = 220 ppb

Occasionally, some incineration byproducts did not meet the delisting criteria. This usually occurred after refractory repairs (the refractory is a chromium-based material) or if the process water was recirculated for too long. Ash and CHEAF media that did not meet the delisting criteria were held at the site for disposal as hazardous wastes. Water that did not meet the delisting criteria was blended with process water that was well below the delisting criteria so that the resulting mixture could be discharged. Testing for TCDD and TCDF was not required because the MIS was proven to destroy CDDs, CDFs, and other toxic organic constituents in the waste effectively during the Trial Burn. However, because this was a research project, samples of the ash CHEAF media and process water that were generated during the Field Demostration were submitted to the Region VII laboratory for low resolution GC-MS dioxin analyses. In all cases, no dioxin was found (Table 9).

Four sites in southwestern Missouri were cleaned up; Neosho Farm, Erwin Farm, and Talley Farm. At the time operations were suspended, material from Verona began to arrive. Currently, there are 600,000 pounds of solids and 60,000 pounds of liquids awaiting incineration at the site. In addition, there are 33,000 pounds of solids and 17,000 pounds of liquids still in Verona. These materials will be shipped to the site when operations resume.

When operations were suspended, EI had an operating on-line factor of 55%. The one element most affecting the on-line factor was the buildup of solids in the SCC. This buildup was a function of the soil being incinerated. A sandy loam river bottom type of soil with no clay content caused a solids buildup in the SCC that necessitated shutdown after an average of 127,000 of pounds were run through the kiln. By comparison, 480,000 pounds of Denney Farm Clay soil were fed by IT Corp. during July and August, 1985, and operations could have continued to 500,000 pounds of throughput before shutdown for cleanout of the SCC would have been necessary.

In order to study the effect of soil type on particulate carryover, a particle size analysis was performed on the incinerated soil fines. Samples were examined through a 27-channel particle size analyzer (0.63-256.09 u) and through a 16-channel particle size analyzer (0.63-20.07 u). Four samples were analyzed:

- Fines from the hydrocyclone sludge, which were carried over through the SCC to the quench sump and then to the hydrocyclones;

- Fines from the SCC when Erwin Farm soil was incinerated;

- Two samples of fines from the SCC when Denney Farm soil was incinerated.

Particle size distribution graphs and tables were prepared (Appendix E). The data indicated that the mean particle size of material reaching the hydrocyclones was 25 u. The mean particle size of incinerated Erwin Farm soil taken from the SCC was 57 u, and the mean particle sizes of the two incinerated Denney Farm soils taken from the SCC were 128 u and 100 u, respectively.

TABLE 9. TCDD ANALYSES OF INCINERATOR BYPRODUCTS

		OUTPUTS (ALL ND*)		
Location	Feed ng/g	Ash ng/g	CHEAF ng/g	Water ng/L
Denney Farm	100-900	0.1	0.1	0.1
Rusha Farm	11	0.1	0.1	0.1
Talley Farm	21.5	0.1	0.1	0.1
Erwin Farm	19.7	0.1	0.1	0.1
Neosho Farm	33	0.1	0.1	0.1

*ND= not detected

The results of the particle size analysis confirmed the observations that sandy loam-type river bottom soils with no clay content form much finer particles upon incineration than those soils (like Denney Farm) that contain clay. The results also show that, for the most part, only very fine soils reach the hydrocyclones.

During this interim period, a design study was conducted by EI to increase the throughput and on-stream factor of the MIS. The following design modifications were recommended:

1. Ram feed system - increase volume from 0.5 ft^3 to 1.2 ft^3 which will increase the feed rate to 79 ft^3/hr;
2. Incorporate an oxygen enrichment system in the kiln;
3. Install a cyclone between the kiln and SCC. The cyclone will be sized for 7000 (SCFM) gas flow at 1900°F and is expected to remove 93% of particles larger than 20 microns;
4. Replace CHEAF with a wet electrostatic precipitator or equivalent particulate scrubbing system. (This step is to improve vacuum control and reduce operating costs--see Lessons Learned, below.)

The proposed modifications are expected to increase the throughput of the unit to 4000 lb/hr, with an on-stream factor of 80%. This would result in an average throughput of 76,800 lb per day. This compares to an average daily throughput of 13,560 lb/day (based on actual throughput during October, November and December 1985) of the present system, and represents a three- to fivefold improvement in the MIS operation.

LESSONS LEARNED

This section is divided into two subsections: planning and startup and extended field operations.

Planning and Startup

This discussion includes the following elements:

- Permitting time and schedule requirements
- Delisting requirements
- Site preparation considerations
- Weather-related problems
- Selection and integration of equipment
- Mechanical design factors
- Health and Safety considerations.

Permitting Time and Schedule Requirements--

Based on the experience gained in Missouri, the permitting process should be started as soon as the site is chosen. The RCRA application followed OSW guidelines and was given both "completeness" and "adequacy" reviews on a coordinated (Region VII/MDNR) basis. The preparation of the detailed Trial Burn Plan, including the Sampling and Analysis Plan and the Quality Assurance Project Plan constituted a significant portion ($>60\%$) of the applicant's permit aquisition effort, with preparation of the field installation design, preparation of the system description, and follow-up activities (such as responding to the reviewer's comments) constituting in descending order, the balance of the effort. Permitting was facilitated by having the initial application carefully prepared and thoroughly reviewed in-house before being submitted as an official application, and by the coordinated State/Federal application review process.

The Permit Application and the site installation plans (including the Trial Burn-related materials) are public information and can be made available to interested parties (see Appendix C, Annotated Index). The Trial Burn Plan for this project, combined with the CCl_4 and PCB portions of the Trial Burn Plan for the liquids tests conducted in Edison, NJ in 1982-1983, could be used to define a single Liquids and Solids Trial Burn Plan to obtain quality-assured data to meet both RCRA and TSCA regulatory standards.

Delisting Requirements --

RCRA regulations classify by-products from a hazardous waste treatment system as hazardous wastes. The options that exist for handling these wastes include:

- Disposal at a hazardous waste disposal facility
- Prove they are nonhazardous and remove them from the list of RCRA-designated wastes (delisting) with land application of the water and disposal of the solid at a local landfill
- Obtain an NPDES permit and discharge to a body of water (scrubber purge stream only).

The delisting permit required analytical tests on every tank of wastewater and on relatively small quantities of treated soil to confirm that the extracts of the material met EP toxicity criteria before discharge or disposal. In retrospect, securing an NPDES permit may have allowed more efficient site operations and decreased analytical costs (due to longer analytical turnaround time) since NPDES permits normally require less frequent sampling and reporting of analytical results. An alternative sampling plan for ash could, in the future, also reduce analytical costs.

Site Preparation--

Even a mobile facility requires a semipermanent site to perform effectively. Minimal site requirements include proper foundations, a covered materials storage and handling building, and access roads that will be adequate in any weather. Site preparation should be completed before processing equipment is brought to the site.

Weather-Related Problems--

Specific problems that arose due to low temperature when the MIS was first operated included:

- Gelled fuel oil;

- Broken drive spline in the shredder drive motor due to the high viscosity of the hydraulic drive fluid;

- Frozen water lines.

Selection and Integration of Equipment--

The MIS was developed as a research and development tool and as such was not designed for processing any specific type of waste material. For future waste site cleanup operations, it is recommended that feed materials be very carefully characterized and that the incineration system be designed, as far as possible, to suit those specific characteristics. Specific problems included:

- The handling capacity of the ram system feeding solids into the rotary kiln was undersized relative to the processing capacity of upstream and downstream equipment;

- The wastewater management system was initially undersized;

- A long period of time was required to bring the SCC to operating temperature following a shutdown;

- The CHEAF was not designed for the high particulate concentrations encountered.

The capacity of the solids ram feeder was determined to be the primary mechanical factor limiting the overall capacity of the incineration system. The ram feeder was significantly undersized and could not supply feed material as fast as the rotary kiln could process it or as fast as the shredder, conveyor, and weigh system could supply it. If the ram hopper was not completely filled when the ram started the discharge cycle, a "balloon" effect occurred, in which the material compressed in the hopper but did not discharge into the kiln. The ram feed also tended to jam, especially when processing wet, sticky materials. The maximum sustainable feed rate attained in the field was approximately 2000 lb/hr.

Tanks had been installed to provide enough storage for six days of wastewater generation. This inventory would allow a three-day delisting analytical cycle (one tank was being filled while the other was being analyzed), but the rate of wastewater generation was significantly higher than planned due to the entrainment of solids from the rotary kiln. More tanks were installed, providing more operating flexibility.

Approximately 6-8 hr were required to return the SCC to operating temperature following each shutdown. Heatup time was prolonged because of air leaks around the kiln seals and ash discharge chute, and the inadequate heat input capacity of the secondary burners. Heatup time was reduced after changing the burners in the SCC.

The primary particulate control device in the MIS air pollution control system is a CHEAF, which utilizes a disposable filter media that rotates through the gas, is sprayed with water, and is discarded. A continuous metal screen loop serves as the support for the filter as it passes through the gas stream. The CHEAF is designed for treating a gas with a low concentration of fine particulates. Inlet particulate loadings to the CHEAF for this application were very high due to entrainment conditions and blinded the filter media, leading to excessive pressure drops across the unit. The filter media also developed holes, and bits of filter media plugged spray nozzles. The price of the consumable media was a significant daily operating cost. Finally, air leaks between the gas duct and the metal screen-supported filter media amounted to 30-50% of the induced draft fan capacity -- an effect that, with small changes, significantly alters the vacuum balance of the incineration system. As a result of these problems, replacement of the CHEAF with a wet electrostatic precipitator is planned.

Mechanical Design Factors--

Mechanical design factors that significantly affected the operability and throughput of the system included:

- Entrainment of solids from the rotary kiln into downstream devices
- Mechanical failures common during plant startup operations
- Location of monitoring instruments
- Selection of interlock conditions and setpoints
- Utilization of nonstandard parts in system fabrication.

Entrainment of solids from the rotary kiln into downstream devices was a persistent operating problem which severely limited the onstream availability of the MIS. Material balance calculations indicated that as much as 10-25% of the soil fed to the rotary kiln was carried over into the secondary combustion chamber, the quench sump, and the CHEAF media.

The most severe effects of the solids carryover occurred in the SCC, which is a horizontal, cylindrical, refractory-lined chamber. Gases from the rotary kiln enter through an Inconel spin vane. Directly downstream from the spin vane are two burners, one at the top and one at the bottom of the chamber. Both burners are mounted so that they fire tangentially into the SCC. The spin vane was a major factor in the deposition of particulates in the front end of the SCC, acting like a cyclonic separator. This was especially true when "Springfield Lagoon Sludge" was fed to the incinerator.

Some solids also carried through the SCC to the air pollution control train. Solids settled out in the quench sump and eventually plugged the quench recycle pump and created suction problems in the quench sump. This problem was resolved by installing a hydroclone on the quench recycle line.

These entrainment losses are common in the chemical processing industry where direct-fired rotary kilns process fine-grained feeds. While a cyclone will be used with the EPA system in the future to control fine particulates being carried into the secondary combustion chamber, other designs of soils heating, such as commercially available indirect-fired calciners, could be used for waste site problems that involve primarily soils decontamination. In actuality, the soils treatment problem is predominantly one of drying the soil, since the contaminant content of the soil is normally much smaller than its moisture content.

A number of mechanical failures occurred during the operation of the system that would be considered "typical" of plant startup operations. Examples include:

- Failure of the kiln seals after a few high temperature operations;

- Interference of the kiln flights with the burner flame and water spray;

- Malfunctioning air compressor ("oil-less") that discharged lubricating oil into the air system, creating problems with instruments and the stack monitoring system (This suggests future use of "oil-free" compressors);

- Cracked seal in the quench pump suction piping allowed air to enter the pump and cause cavitation;

- Neutralization of HCl in the quench sump led to the formation of CO_2 gas and subsequent loss of suction head in the quench recycle pump during periods of high chlorine feed rates;

- Failure of the induced draft fan clutch;

- Failure of drive belt between the diesel engine and induced draft fan;

- Weld cracking in the quench elbow entrance venturi caused by differential expansion between the hot gas side (up to 2200°F) and the quenched gas side (180°F).

The design of the MIS utilized a large number of instruments that were read near the point of parameter measurement rather than in a single control room. This distribution of the instrument readout locations required additional labor to collect monitoring data and prevented a single operator from being able to change one operating parameter while simultaneously observing the effect on a second operating parameter.

A number of interlocks were built into the system to ensure safe and environmentally responsible operation of the unit and to conform with permit requirements. High and low setpoints were established for a number of operating parameters (combustion temperatures, excess O_2 concentration, recycle water flows, pressure differentials, waste feed rate, fuel feed rate, air flow rate, etc.). Excursion of an operating parameter outside of the range would trigger an automatic feed system shutdown. In retrospect, operating ranges for several parameters were set with ranges that were too narrow, and it was difficult to control a number of independent parameters automatically. In some situations, the control system would trigger an automatic shutdown when it would have been preferable that an alarm and not a shutdown be triggered after a predetermined amount of time elapsed, during which attempts would be made to bring the system back into compliance. For example, an automatic shutdown occurred each time the pressure differential in the air pollution control system dropped below the lower setpoint, often triggered by a hole in the CHEAF media. This problem could have been quickly corrected by an operator.

The solid waste feed rate was cross-checked by comparing the feed rate recorded by the solids weigh hopper with the weight of the drums fed by operators. The solids were metered into the incinerator by a weighing system that controlled the quantity of each charge and the charge frequency. The weigh hopper system was calibrated before and during the trial burn by a trained technician. However, the weigh cells were calibrated without the incinerator operating and without the influence of operating factors such as kiln vacuum, vibration, and solids buildup in the hopper. Since these factors affect the accuracy of the weigh cell output, an independent technique was used to verify the solids feed rate. The weight of each drum of soil was measured and totaled over a Trial Burn test run. The scales used for drum weighing were calibrated and the tare weight of the drums determined. This technique provides a very accurate solid feed rate if the time period is long enough to average out short-term fluctuations in the solids feed system. One problem encountered in comparing feed rates by these two techniques is the time factor offset caused by the delay between the unloading of a weighed drum and its passage through the weigh cell hopper. This delay is approximately 30 minutes and becomes less important over the 9-10 hour periods associated with a test run. The feed rates recorded by the weigh cell system were 6-23% higher than the recorded drum weights. The drum weight feed rate is considered to be much more accurate and was used for all trial burn test calculations. In contrast, the weigh cell feed rate provides a good indication of how constant the solids feed rate is during a test run.

Health and Safety Considerations

The primary lessons regarding health and safety that were learned from the Missouri experience included:

- Need for contractural commitments between contractor and subcontractors regarding health and safety requirements; and
- A health and safety plan that accommodates extreme changes in weather conditions and specifies levels of personnel protection based on the results of industrial hygiene monitoring.

A detailed health and safety plan that specified appropriate levels of personnel protective equipment and acceptable work practices was prepared at the start of the project. This plan, however, did not have input from the subcontractors. Constant enforcement was needed to ensure that operating personnel conformed to these safety procedures. In addition, personnel turnover required contractural verification that all personnel had received adequate health and safety training. This situation could be improved in the future by making the health and safety plan available to subcontractors during contract negotiations, allowing for the subcontractors input and suggestions, then making adherence to the health and safety plan a condition of the contract.

The original health and safety plan was prepared for operation during September and October, but actual site operations began in January during extremely cold conditions. The respiratory protection had to be modified to prevent fogging of the respiratory protection equipment.

During July and August, however, heat stress was a major concern during operations. A positive pressure respirator, Racal Breathe-Easy Seven (powered air purifying respirator), with a Racal AP3 organic vapor and high efficiency particulate air purifying elements, aided in reducing heat stress. However, the efficiency of operating personnel was greatly reduced (and the costs signficantly increased) by the required personal protective equipment.

Industrial Hygiene Requirements--

Personnel and area air monitoring was performed at the site during April 3-9, 1985. The monitoring study disclosed the presence of trace levels of dioxin contamination in the air inside the solid and liquids feed building. It was necessary to upgrade the level of respiratory protection from full face cartridge respirators to powered air purifying respirators that operated under positive pressure.

The original health and safety plan that was developed for the site was rather general. As site operations progressed, the health and safety plan was modified to reflect the needs for each operational area as established by field experiences.

Sampling and Analytical Parameters--

The sampling and analytical parameters were associated with the accurate definition of process feed and effluent streams. Quality assurance/quality control for these data was defined in the QAPP and included both internal QA (ITAS - primary laboratory) and external QA (EPA Region VII/Midwest Research Institute - reference laboratory). External QA of the Trial Burn data was accomplished by split sample analysis by a reference laboratory on key samples.

The key Trial Burn samples were analyzed for 2,3,7,8-TCDD/CDF, total TCDD/CDF, and other selected PCDDs/CDFs. [See the Dioxin Trial Burn Report, Annotated Index.] The results from the primary and reference laboratories are summarized in Table 10. It is clear from Table 10 that tne results from the two laboratories are in good agreement.

Because of the sensitivity of the Midwest Research Institute (MRI) instrumentation (Kratos Model MS-50 HRGC/MRMS), their data showed a number of positive 2,3,7,8-TCDD values which were due to trace levels of the chemical in the EPA spiking solution or to contaminated solvent. A number of samples contained low but measurable amounts of other PCDDs and PCDFs. Octachlorodibenzodioxin was particularly common.

Extended Field Demonstration Activities

An isolated field operation presents some unique personnel problems. Individuals assigned to the field operation must understand the nature of field operations and they should be briefed in advance about the conditions present at the site. The power of mood and attitude is immense, and all personnel have to be concerned partners in making the operation a success. Technical and tactical innovations are frequently necessary to keep the operation on-line, and personnel have to be selected who are both competent and flexible enough to handle such situations. The proficiency level and alertness of the operators affect the stage at which an operating problem is discovered. With alertness and proficiency, minor problems can be corrected quickly. Without alertness, proficiency, or both, minor problems can turn into major operating interruptions.

The management staff consisted of a project manager, a field accountant/procurer, a maintenance supervisor, and an instrument/electrical supervisor. These people were assigned full-time and were not rotated. This provided a continuity of effort. Operating personnel were subcontracted from Process Operators International (POI) of Houston, TX and Durbin Construction Company of Ozark, MO. POI personnel generally worked 14 days of 12-hour shifts, with 7 days off, and were provided travel and per diem expenses. Durbin personnel typically worked 12-hour shifts.

The project manager must establish ground rules early in the operation. This is important, not only with staff, but with the operators and other subcontractors. Individuals have to know what their responsibilities are. In remote areas, hundreds of miles from the home office, some people left on their own tend to become unstructured rather quickly. It is up to the project manager to establish discipline and motivation.

The availability of spare parts at the site has major economic consequences, especially if operations must be suspended until a new part arrives. Most of the daily operating expenses, for example, labor costs, continue even if the incinerator is not operating. The maintenance and instrument/electrical supervisors must maintain good access to spare parts. They must be able to anticipate problems and have spare parts available when needed, keeping downtime to a minimum. In an operation that runs 24 hours a day, and 7 days a week, it can be expected that suppliers will be closed about 75% of the time that the operation is active. A part that costs under $100 can conceivably suspend the operation for days. This situation is worse if the breakdown occurs over a weekend or holiday.

TABLE 10. COMPARISON OF PRIMARY AND REFERENCE LABORATORY RESULTS FOR 2,3,7,8-TCDD

	Test 2-2		Test 2-3		Test 2-4		Test 2-5	
SAMPLE MATRIX	ITAS[a]	EPA/MRI[b]	ITAS[a]	EPA/MRI[b]	ITAS[a]	EPA/MRI[b]	ITAS[a]	EPA/MRI[b]
Liquid Feed	248 ppm 250 ppm	321 ppm 313 ppm	357 ppm	323 ppm	330 ppm 198 ppm	204 ppm 251 ppm	270 ppm 179 ppm	273 ppm 219 ppm
Solid Feed	101 pb	76 ppb	382 ppb	737 ppb	1,010 ppb	1,785 ppb	770 ppb	712 ppb
Fuel Oil	ND (0.11 ppb)	ND (51 ppb)	ND (1.7 ppb)	ND (1.6 ppm)	ND (5.5 ppb)	ND (0.97 ppm)	ND (1.8 ppb)	ND (0.75 ppm)
Kiln Ash	ND (0.20 ppb)	ND (0.001 ppb)	ND (0.08 ppb)	0.0005 ppb	ND (0.10 ppb)	ND (0.0004 ppb)	ND (0.04 ppb)	0.0006 ppb
CHEAF Filter	ND (0.25 ppb)	ND (0.55 ppb)	ND (0.05 ppb)	ND (0.05 ppb)	ND (0.08 ppb)	ND (0.039 ppb)	ND (0.09 ppb)	ND (0.049 ppb)
Stack MMS Train								
particulate	ND (1.9 ng)	0.16 ng	4.6 ng	1.1 ng	ND (0.80 ng)	ND (0.34 ng)	ND (0.9 ng)	ND (0.6 ng)
condensate	ND (3.1 ng)	0.54 ng	ND (0.40 ppt)	0.17 ng	ND (2.0 ng)	0.45 ng	ND (9.0 ppt)	0.49 ng
Florisil	ND (3.2 ng)	0.69 ng	ND (0.79 ng)	ND (0.2 ng)	ND (4.0 ng)	ND (0.2 ng)	ND (1.0 ng)	ND (0.25 ng)
XAD	ND (0.57 ng)	ND (0.16 ng)	ND (1.0 ng)	ND (0.2 ng)	ND (2.0 ng)	ND (0.2 ng)	ND (1.0 ng)	ND (0.4 ng)
composite	ND (5.0 ng)		ND (4.0 ng)		ND (1.0 ng)		ND (2.0 ng)	

(a) IT Analytical Services

(b) EPA Region VII and/or Midwest Research Institute

An example of the seriousness of this problem occurred with a spare shredder motor. After previous spline failures at low temperatures, a spare motor was purchased. Upon having another spline failure, it was discovered that the spare, valued at approximately $12,000 delivered, did not fit and the existing hydraulic motor had to be rebuilt, a process that cost the project a week of downtime in addition to $7,000 in air freight costs and expedited rebuilding costs.

Part of the procurement responsibility involves the question of renting or purchasing equipment. In order to make an appropriate decision, the length of stay at the site must be defined early in the project.

A preventive maintenance program is essential to keep the MIS operating efficiently. A regular maintenance schedule, involving vendor representation, must be established early in the project, and followed diligently.

A "cold cleanout" of the SCC (where the system was allowed to completely cool such that personnel could enter the secondary chamber to remove accumulated solids) took anywhere from 60 to 90 hours, with an average feed interruption of approximately 70 hours. Cold clean-out time requirements were a function of the material being incinerated. A moist soil high in clay content would cause some jamming problems in the front-end of the feed system, but the carryover from the kiln to the SCC was low. The Denney Farm soil had a high clay content; the soil from Erwin Farm, Rusha Farm, Talley Farm, and Neosho was a fine sandy loam which went through the feed system very well. However, the carryover from the kiln to the SCC was significant (up to 25% of feed), necessitating a cold clean-out after an average of 127,000 pounds of soil were fed.

During the extended Field Demonstration the production on-line factor was 55% (therefore the unit was down 45% of the time). Approximately 90% of the downtime was attributable to the cleanout of the particulate carryover from the kiln to the SCC. In an attempt to improve the efficiency of these cleanouts and improve the on-line factor, various methods were tried, and the following conclusions were drawn:

(1) Cutting off burner #1 (kiln burner that fires in a slightly downward position) resulted in less dust or particulate matter being stirred up in the kiln. This made a marginal difference in the carryover rate.

(2) Changing the feed rate had little, if any, effect on the total production between clean-outs. That is, a lower feed rate just resulted in a longer time to accumulate particulates in the SCC to a level necessitating shutdown.

(3) Wetting the soil with water accumulated from personnel decontamination operations put an additional heat load on the kiln, and made it more difficult to maintain a vacuum. It had little effect on controlling particulate carryover.

(4) "Hot clean-outs" of the SCC (where the feed was interrupted but the system was maintained close to operating temperature) resulted in feed interruptions of 2-3 hours and increased the production between the times needed for cold-cleanouts. In general, approximately three hot cleanouts were required between cold clean-outs.

(5) An augered hopper installed below the new SCC extension did not extend the time between either hot or cold cleanouts, because the particulate material did not collect in the drop out areas as expected. It was swept further down into the SCC.

(6) Operating with the ID fan at a flow rate as low as possible (-26 in w.c.), reduced the rate of particulate carryover from the kiln into the SCC.

(7) Tuyere air introduced into the kiln blows particulate matter and increases the particulate carryover rate. An attempt was made to eliminate the tuyere air while feeding the soils. However, when trash was fed with soils, there was not sufficient oxygen available and tuyere air had to be used.

A number of other important lessons were learned during the extended Field Demonstration of the MIS. When trash (originating from sampling and cleanup operations), including contaminated clothing, plastics, boots, CHEAF media, etc., was fed to the incinerator, the system operators experienced control difficulties due to the high degree of combustibility and variability of these materials. Because of this, there were frequent shutdowns due to vacuum loss, plugged CHEAF media, high carbon monoxide levels, low oxygen levels and mechanical problems in the weigh hopper gates and ram feed. A mixture of soil and trash alleviated some of these problems.

Although the solids feed system was designed to handle the shredding of metal drums, this process was time consuming and took anywhere from 5 to 20 minutes for each drum.

A common practice after sampling a drum of liquid waste is to break off the glass sampling tube in the drum. This and other foreign material collected in the liquid waste were pumped into the liquid feed tank without being filtered, and subsequently deposited on the seat of the internal relief port of the waste feed oil pump. This caused the pump to recycle internally rather than to move liquid to the kiln waste nozzle. Drummed liquids, therefore, should be filtered prior to being added to the main liquid feed tank.

The feeding of liquid wastes was sometimes limited by its Btu content. Also, because of permit conditions it was necessary to keep one main burner on for regulatory compliance. Consideration will be given to tying the liquid waste feed into one of the two main burners so that the burner can be used for either normal fuel firing or liquid waste incineration. In this manner, increased feeding of liquid waste can be achieved, along with better atomization and combustion air mixing.

The SCC gas outlet venturi was a constant source of problems. Materials collected on the venturi surface and alter the throat diameter, causing the flowmeter to read incorrectly. The flowmeter indication was usually higher than the actual flow rate. This device has subsequently been abandoned as a flowmeter.

Mineral deposits adhering to the walls of the CHEAF inlet duct were a serious problem at the beginning of the field demonstration because they caused the emergency vent gates to stick. Two actions were taken to alleviate this problem:

1. The water softener was repaired, reducing the amount of minerals deposited on the duct walls, by removing one of the sources of these minerals.

2. Spray nozzles were installed in the inlet duct to flush the walls, keeping the minerals carried from the process in suspension as the walls were washed.

Water to the hydroclones had to be over a certain minimum pressure in order for the hydroclones to work well and not plug up.

Maintaining the pH of the CHEAF sump liquid to the minimum allowable value under the permit had the advantage of keeping the salt build-up on the CHEAF in check and maintaining the necessary vacuum in the system.

Frequent cleaning of the burner tips were required for good operation. Cleaning the tips once per shift optimized their performance. Ceramic pumps in the quench recycle, CHEAF recycle and scrubber recycle service wore out every 2 to 6 weeks. Impellers became clogged with grit, CHEAF media, and "Tellerettes" ^{R}, and started to wear away the pump casings. Filters were tried but they also became clogged almost immediately. A steel pump (Aloyco 20) was then used in the quench recycle service and it performed much better than any ceramic pump. The steel pump was apparently able to grind up the material causing the clogs.

Water storage was in short supply at the site. Wastewater was stored pending analysis for Hg, Se & Ca according to RCRA delisting criteria. Approximately 6000 gallons/day of wastewater was generated even though the on-stream factor of the incinerator was 55%. Water storage was particularly problematic over weekends or if a tank of water was held for blending or resampling. Additionally, when the incinerator was started up after a shutdown that involved refractory repair, the wastewater generated usually failed the delisting requirements because of a high concentration of heavy metals (e.g., Cr). This added to the water storage problem.

The feed rate of some contaminated liquids could be increased by mixing with other liquids. For example, trichlorophenol still bottoms alone could be fed to the incinerator at a maximum rate of 35 lb/hr due to the problem of controlling temperature in the kiln. However, when the still bottoms were mixed with methanol (three parts still bottom material to one part methanol), the mixture could be fed at the rate of 160 lb/hr. This meant that the still bottom fraction of the mixture was being fed at the rate of 120 lb/hr, over a threefold increase.

On two occasions, a buildup in the kiln formed a dam and blocked other solids from passing through. Eventually these solids started leaking out the front (feed-end) kiln seal. On one of these occasions a mixture of Erwin Farm soil and hexane was being fed to the incinerator. The hexane may have had impurities in it that bonded to the dust and caused the dam to form halfway down the kiln. The material that built up was crusty on the outside and soft on the inside. The problem was solved by reducing the feed rate of this mixture from 80 lb/hr to 50 lb/hr.

Operators were not able to keep the conveyor from the "hot zone" loaded when the solids feed system was handling very wet soil. The wet soil tended to bridge on a "dam" designed to limit the height of material on the conveyor. Wet material had to be pulled through the conveyor dam manually.

The hydraulic drive of the shredder is temperature sensitive. Attempting to start the shredder when the temperature fell below 60^{0}F caused the drive motor "spline shaft" to break. Therefore, the shredder had to be operated continuously if the temperature was less than 60^{0}F. If the shredder could not be operated continuously, it had to be protected with an electric blanket, and the hydraulic lines heat traced. The results of a break in the spline shaft were discussed earlier in this report. These problems are symtomatic of hydraulic system operations in cold weather, and suggest that special considerations may have to be provided in the equipment design to enable effective cold weather operations.

ECONOMICS OF MOBILE INCINERATION SYSTEMS

The unit cost ($/ton) of processing waste material by a mobile incinerator strongly depends on the incinerator's capacity, on-stream factor (availability), and associated cost factors.

Factors Affecting MIS Capacity

The capacity, i.e., the rate at which the waste material can be fed into the MIS, results from a complex interaction between the physical parameters of the system, the operating conditions necessary to meet the regulatory requirements with respect to stack emissions and delistable ash from the kiln, and the waste characteristics. These major items and their interactions are illustrated in Figure 5 and are described briefly below.

Mobility imposes the primary constraint on the maximum kiln and SCC size and weight that can be accommodated on semi-trailers. The specific sizes of the kiln and SCC selected for the MIS are the largest possible within the size and weight restrictions for the semi-trailers. The ram feed system presently used in the MIS has a volume of 0.5 ft^3 with a cyclic period of 55 seconds. Thus, for a ram cyclic period of 1 minute, and a waste feed bulk density ranging between 65-100 lb/ft^3, the present ram feed system capacity is 1950-3000 lb/hr.

The kiln volume (236 ft^3) limits the amount of solids that can be processed effectively. The kiln vendor recommends that the kiln fill factor should not exceed 15-20% of its volume. Furthermore, a certain minimum kiln ash temperature and solid residence time (in the kiln) must be provided in order to produce delistable ash.

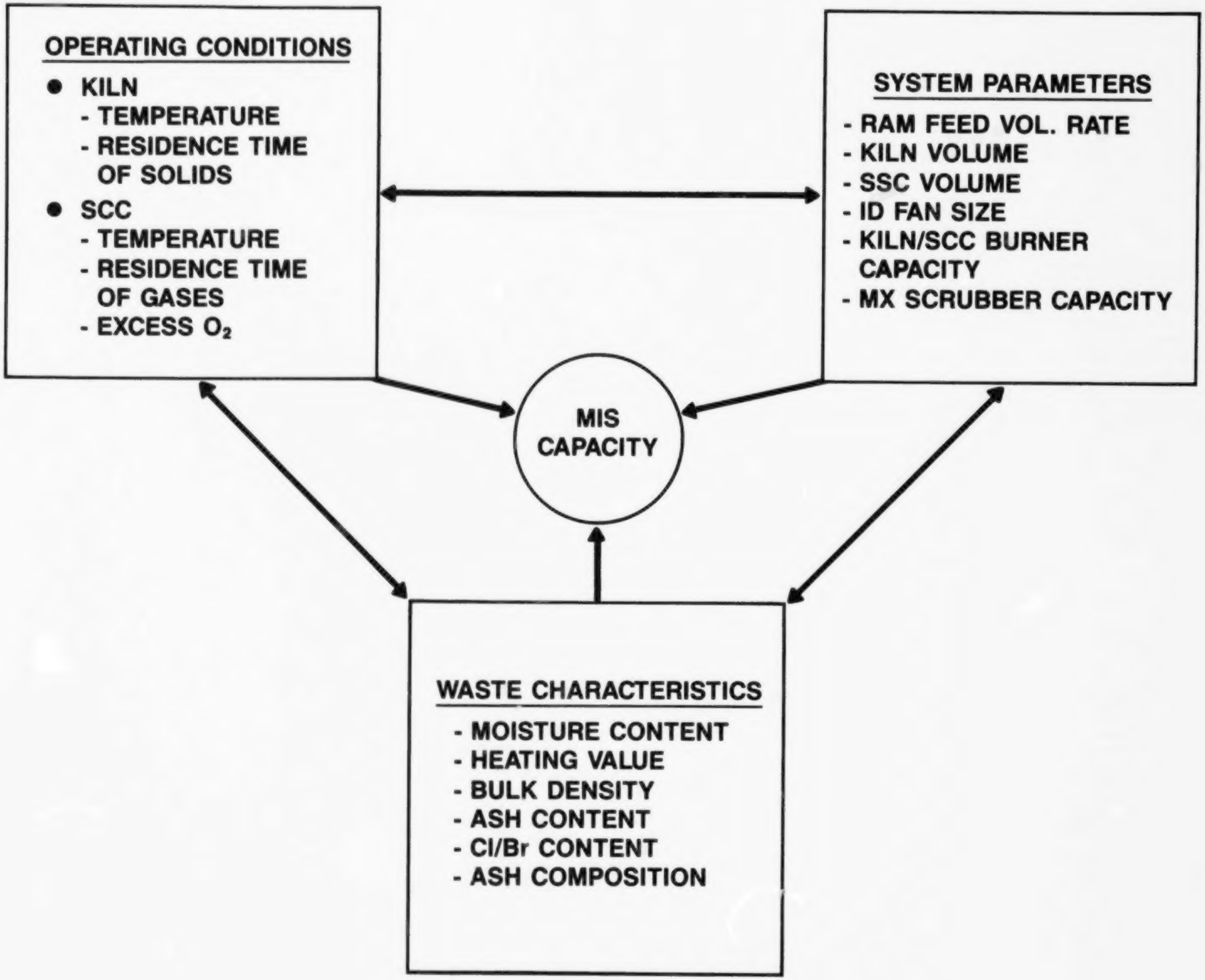
OPERATING CONDITIONS
● KILN
- TEMPERATURE
- RESIDENCE TIME OF SOLIDS
● SCC
- TEMPERATURE
- RESIDENCE TIME OF GASES
- EXCESS O_2
SYSTEM PARAMETERS
- RAM FEED VOL. RATE
- KILN VOLUME
- SSC VOLUME
- ID FAN SIZE
- KILN/SCC BURNER CAPACITY
- MX SCRUBBER CAPACITY
MIS CAPACITY
WASTE CHARACTERISTICS
- MOISTURE CONTENT
- HEATING VALUE
- BULK DENSITY
- ASH CONTENT
- Cl/Br CONTENT
- ASH COMPOSITION

Figure 5. Factors affecting MIS capacity

The latter two parameters for the MIS have been conservatively selected to be 1800°F and 30 minutes, respectively. Again, a conservative limit for the fill volume of 15% allows a waste feed capacity of 4600-7000 lb/hr for a waste feed bulk density of between 65-100 lb/ft^3.

In order to meet the regulatory limits shown in Table 2 (pg 11), the SCC must be operated at 2200°F, have an excess oxygen level of more than 3%, and a minimum gas residence time of 2 seconds. The SCC volume (531 ft^3), the maximum for a mobile incinerator, imposes a constraint on the maximum gas flow rate of 15,930 acfm through the SCC. The waste characteristics that affect the gas flow rate through the SCC include moisture content, heating value, and ash content.

During the Trial Burn of the MIS, lagoon sludge containing approximately 3800 Btu/lb was processed. The feed rate of the system had to be reduced to 1000 lb/hr in order to accommodate the gas produced. When processing soil with a very low or no combustible content, a rate of 2000 lb/hr or more could be maintained. For soils with low heating value, higher processing rates can be achieved if the soil moisture content is low, whereas for wastes with high heating value some moisture is beneficial in that it prevents overheating in the kiln.

The chlorine and bromine contents of soil are important because of their impact on the performance of the Mass Transfer Scrubber. Bromine requires a special analysis to determine compatibility with materials of construction of the incinerator and the stack gas monitoring system. Ash composition is important because of its impact on the maximum kiln temperature that may be used without causing any slagging.

The capacity of the present MIS system is primarily limited by the ram feed volumetric rate as well as by its gas-handling capability. Therefore, the proposed modifications to the MIS are aimed at increasing its capacity and include: increasing the volume of the ram feed trough and replacing one of the air burners by an oxygen-assisted burner. The oxygen burner reduces the quantity of total gas in the system, thus the waste material feed rate (and associated water vapor) can be increased without exceeding the gas flow rate limit in the SCC.

On-Stream Factor

The on-stream factor includes the contribution of both the forced outages and the scheduled outages for system maintenance. The lost time during the mobilization of the unit to a new site is not included in the on-stream factor as used in this report. As mentioned earlier in this report, an on-stream factor in the range of 45-55% has been experienced in this R&D prototype.

Major problems, discussed in detail in previous sections, concerned the ram feed system and the accumulation in the SCC of particulates carried over from the kiln. An on-stream factor of 50% is assumed for the purpose of determining the economics of the MIS.

Cost Factors

In general, the costs for an MIS fall into three categories: capital costs including all costs that can be amortized over the service life of the system; mobilization/demobilization costs associated with startup and shutdown at a given site and can be amortized while the unit is located (and operated) at a given site; and operating costs to operate and maintain the system. Recognizing that the EPA MIS is an R&D prototype, the actual costs incurred during its development were used only as a guide to determine the costs associated with a similar incineration system. A detailed discussion of various cost components involved in each of the three cost categories and the factors that affect them, together with an economic analysis of the MIS based on EPA cost experience, is provided in the following.

Capital Costs --

As mentioned above, these are costs that can be amortized over the entire system life and include costs for:

- Design & Fabrication
- Operating Procedures & Operator's Training
- Initial Startup & Shakedown
- Trial Burn & Permitting

A summary of these capital costs for an incinerator similar to the MIS is given in Table 11. The basis for these estimates and the factors that affect them are described below.

Design and Fabrication Costs --The design and fabrication costs (including design, engineering, materials and equipment procurement, fabrication, and installation) for reproducing the EPA Mobile Incineration System were based on a study performed by IT Corporation (see Annotated Index, EERU Mobile Incineration System Capital Cost Estimate). The estimate (December 1983 prediction) ranged from $1.6 million to $2.3 million. It included the cost of all subsystems and components installed on the three main trailers and the stack monitoring trailer with its analytical equipment. The cost of tractors for the transport of the trailers were not included. In addition, the cost of the hydraulic ram (used to feed solids to the rotary kiln) was included, but the cost of the shredder and other associated solids feed system components were not. The design, fabrication, and installation of the solids feed system, which occurred in 1984, cost an additional $583,000. A conservative estimate is used in Table 11 for these costs.

Operating Procedures Development and Operator Training --The second major one-time cost item in the development of an incinerator system is the creation of operating procedures and a program to train operators. These costs include: the preparation of an operating manual and a safety manual, and the development and implementation of an operator training program, equipment decontamination procedures, and automated data management and reporting procedures.

TABLE 11. CAPITAL COSTS

Item	Cost (in thousand dollars)
Design & Fabrication	2,900
Operating Procedure & Operator Training	200
Initial Startup & Shakedown	600
Trial Burn & Permitting	1,400
TOTAL CAPITAL COSTS	5,100

The total cost of these administrative activities for the MIS was $113,000. The cost to provide medical monitoring, safety training, environmental awareness training, and specific task training was approximately $2000 per operator. For a crew of 27 operators, the total cost of such training, including the employee wages, is estimated to be $90,000.

Initial Startup and Shakedown --After the incineration system has been fabricated, operating procedures developed, and operator training implemented, the next step in the development of the project is a shakedown of the unit. The MIS shakedown occurs in two phases: a "cold" test phase in which each of the incinerator subsystems are operated without igniting the burners, and a "hot" test phase where the burners are turned on, the kiln and SCC brought up to operating temperatures, and "clean" soils and liquids passed through the system. In order to ensure a successful operation, the normal operating crew plus a team of specialists must participate in the system start up and shakedown. A total shakedown of an incinerator similar to the MIS may take several weeks and cost $150,000 per week or more. Based on a reasonable (4 weeks) initial startup and shakedown duration, the total cost of this item is estimated to be $600,000. If shakedown reveals the need for any long-lead materials or modifications, the costs for shakedown can increase dramatically.

Trial Burn and Permitting --The costs associated with regulatory compliance issues for an incinerator are numerous and varied. Establishing permit requirements, preparing initial permit applications, supporting permit application information throughout the permit issuance process, up to and including final permit issuance, all need to be addressed during the budgetary process. Once the final permits are issued, there are continuing costs to ensure on-site permit compliance, e.g., record-keeping requirements, required inspections, response to surveys by permitting agencies, and reporting requirements (see Annotated Index, Permit Compliance Summary for the EPA Mobile Incineration System at Denney Farm). In addition to obtaining the necessary permits to operate the incinerator, additional costs will be incurred if efforts are made to delist the byproducts of the incineration (for example, ash and process water).

The initial permitting and delisting effort in support of the MIS in Missouri required over one work-year of effort and cost $112,000. Note that much of the information that was developed for the permit application in New Jersey was used for the permitting effort in Missouri. The cost of developing application materials and associated activities for the MIS in New Jersey to prepare for both a generic RCRA/TSCA Liquids Trial Burn and a separate Field Demonstration was more than $300,000. An important point is that once a mobile unit is permitted at one site, the cost of permitting it at the next site is substantially reduced. This trend may continue as permitting requirements for mobile treatment systems are further streamlined by Federal and State regulatory agencies.

Additional costs associated with regulatory compliance include the preparation of a trial burn plan, along with a sampling and analysis plan, and a QA/QC plan, followed by the execution of a RCRA/TSCA Trial Burn to prove system DRE performance. The cost for developing this documentation for the Missouri operation, and performing the site-specific trial burn on dioxin-contaminated liquids and solids (including elaborate analytical support and a highly detailed trial burn report) was $1.1 million.

Mobilization and Demobilization Costs --

As mentioned earlier, these costs occur only once for an incineration system for a specific site and therefore can be amortized while the system is used at a given site. These costs are site specific and may vary widely depending on the nature and location of the site. They are summarized in Table 12 and include the costs for: site preparation and logistics, transportation and setup, on-site system check-out, site-specific testing for proof-of-performance, and decontamination and demobilization.

Site Preparation and Logistics Costs --The costs associated with site preparation and logistics include logistics planning and management, detailed site design, permanent site construction, auxiliary equipment services, temporary site facilities, water conditioning, emergency and safety equipment, site staff support, spare parts, consumable supplies inventory, and interim maintenance and winterization (Table 13). The extent of site construction varies with the nature of the site and local climatology. In Missouri an all-weather building was needed to house the incinerator so that cold weather operations could proceed. Continuous maintenance and winterization of the incinerator is included because these tasks must be on-going, even if operations at the site are temporarily suspended. The cost associated with these tasks for the Denney Farm site was $896,571. Soil excavation, feedstock preparation, and handling costs are not included. These costs strongly depend on the nature of feed, e.g., a waste feed with a high concentration of a volatile contaminant may need to be stored in separate buildings with special adequate ventilation to provide for fugitive emission control. Similarly, solids awaiting incineration must be protected from rain since moisture content has a strong effect on the processing rate.

Transportation and Set-up Costs --The cost of transportation and set-up includes disassembly of the mobile incinerator and its associated equipment at its present location, and moving the equipment to its new location. The MIS had to be moved from central New Jersey to southwest Missouri and involved 12 trailers: three incinerator trailers, a feed system trailer, four trailers of auxiliary equipment, the HEPA filter trailer, a decontamination trailer, the monitoring trailer, and a spare parts and tool trailer. In addition, an operations trailer and four other storage trailers were moved to the site from local suppliers. Once on-site, the equipment was unpacked and assembled by operating crews.

TABLE 12. MOBILIZATION AND DEMOBILIZATION COSTS

Items		Cost (in thousand dollars)
Site Preparation and Logistics		900
Transportation and Setup		200
On-site Checkout		100
Site-specific Permitting		200
Decontamination and Demobilization		600
	TOTAL	2,000

The cost of these tasks at the Denney Farm site was $161,000. (Note that it may be necessary to obtain and train a new operating crew if the former crew used during shakedown testing is not available for the site-specific work.)

Cost of On-site Checkout --Following the set-up of a mobile incineration system at a site, it is necessary to shakedown the system to ensure that no damage occurred as a result of disassembly, shipment, and reassembly. This activity also serves as a site specific dress rehearsal for operating personnel. The cost of the initial shakedown program for the MIS at the Denney Farm site was $92,000. (This does not include numerous startup and cold weather difficulties experienced during January - April, 1985.)

Site-specific Permitting --In spite of the fact that a generic (stack-emission related) trial burn is initially performed and the necessary permits obtained, in some cases, another trial burn at each site may be required for verification of the cleanliness of ash and water byproducts when feeding site-specific water. As mentioned earlier, the costs of permitting at each new site should be substantially lower than the initial permitting cost, and may involve only a relatively short-term operation to obtain samples for subsequent analysis.

Decontamination, Demobilization, and Other Shutdown Costs --After completing activities at a specific site, a mobile incinerator must be decontaminated and disassembled before being moved to its next location.

The cost to shut down a facility will vary greatly and must be estimated on a site-specific basis. The estimate for shutting down the operation at the Denny Farm Site in McDowell, MO is as follows:

o	Scrape and burn top layer of soil from Hot Zone (1 week operation)	120,000
o	Field Labor (10 men 6 weeks)	100,000
o	Field Supervision	60,000
o	Material	40,000
o	Sampling and Analytical	50,000
o	Shipping Charges	50,000
o	Return Equipment Rental Charges	15,000
o	Exit Physicals	10,000
o	Rental Equipment	10,000
o	Site Security During Shutdown	6,000
o	Travel and Living During Shutdown	10,000
o	Utilities During Shutdown	5,000
o	Home Office Support	30,000
o	Miscellaneous 10%	50,000
	Total	$556,000

TABLE 13. COSTS ASSOCIATED WITH SITE PREPARATION AND LOGISTICS

Items		Cost
Logistics planning and management		$164,924
Detailed site design		$ 68,577
Permanent site construction (including upgrading of entrance road		$465,490
Auxiliary equipment services		$ 33,563
Temporary site facilities Water Conditioning Emergency and Safety Equipment Site staff support		$ 60,500
Spare parts (initial inventory)		$ 30,417
Consumable supplies		$ 25,000
Interim maintenance and winterization		$ 48,100
	TOTAL	$896,571

Operating Costs --

These costs include all labor and material costs incurred to operate and maintain the incinerator system in the field. For an MIS, these costs constitute the largest fraction of the overall economics.

The EPA Mobile Incineration System is an R&D prototype and therefore numerous developmental modifications had to be done in the field. In addition, due to the field problems experienced in this R&D project, the total amount of waste treated was much smaller than the system capacity.

The MIS Field Demonstration started on July 23, 1985 and ran to February 6, 1986. IT Corporation operated the MIS until August 27, 1985, after which operations were taken over by Enviresponse, Inc. (EI). Operations were suspended during September 1985 to October 3, 1985 for administrative reasons, and again during the 1985 Christmas holidays. Otherwise, operations were continuous at 24 hours per day, 7 days per week. During this time detailed information was collected regarding the cost to operate the system and is summarized in Table 14.

Field Labor -- A review of the field labor costs during the 116 days that EI was operating contractor (October 3, 1985 to February 6, 1986, less the Christmas holiday shutdown of ten days) shows that the operation of the MIS is very field-labor intensive. Labor costs, including on-site costs and home office support, amounted to over 66% of the total operating costs. Four operators were utilized per shift: a shift supervisor, a kiln operator, a monitoring specialist, and a utility operator. The operators worked two weeks, 12 hours per day, and then had one week off. Therefore, three shifts were required to man the unit during the Field Demonstration.

From a management viewpoint, operating on two 12-hour shifts is very expensive due the amount of overtime involved. This expense was, in part, necessitated by the fact that incinerator operators brought in from out of the area had to be enticed to work at a remote field location by the promise of overtime. Plans are currently being devised to train local people to act as operators, so that future operations can be run using three 8-hour shifts.

One-half of the field labor cost, and a little more than one-third of the total operating cost were for the services of a local maintenance and construction firm. This firm was responsible for all work in the hot zone, such as feed preparation and handling. They were also responsible for ash removal, maintenance labor, janitorial services, running errands, transporting ash, CHEAF media and other contaminated material, etc. Typically, they had ten people working during the day and five working during the night (Table 15). Feed and ash handling required use of numerous 55-gallon drums; automation of the feed and ash handling system may reduce the labor costs significantly.

Service calls by various vendors were included in maintenance material costs as part of a preventive maintenance program.

Other Operating Costs -- Fuel for the Mobile Incinerator System accounted for approximately 9% of the total operating cost. One of the factors affecting fuel costs was the heating value of the solids and liquids being incinerated.

TABLE 14. TOTAL OPERATING COST BREAKDOWN*

ITEM	COST $K	% OF TOTAL
Feed preparation, ash removal and maintenance subcontractor	670	35.4
Operating Subcontractor	331	17.5
Maintenance materials	196	10.4
Management (EI) Field Staff	161	8.5
Fuel	159	8.4
Equipment Rental	84	4.4
Filter Media	65	3.4
Home Office (EI) Support	60	3.2
Sampling and Analytical Subcontractor	42	2.2
Field Modification	35	1.8
Subcontracted Site Security	35	1.8
Sample Analyses (Lab costs)	27	1.4
Safety Equipment	13	0.7
Caustic	12	0.6
Specialty Gases	3	0.2
Office Supplies	2	0.1
TOTAL	1,895	100

*Based on 116 days of actual operation

TABLE 15. MOBILE INCINERATION SYSTEM OPERATING CREW

Job Title	Job Description	Skill Level
Project Manager	Has overall responsibility for site operation.	Highly skilled
Shift supervisor	Responsible for overall operation at the site during the shift.	Highly skilled
Kiln operator	Monitors and controls incineration system.	Highly skilled
Monitoring trailer specialist	Operates and maintains Continuous Monitoring Trailer.	Highly skilled
Utility operator	Monitors process water subsystems of the incinerator.	Highly skilled
Ash handler	Responsible for containerizing and storing the generates ash.	Laborer
Maintenance supervisor	Supervises maintenance mechanics and maintains inventory of equipment.	Skilled
Maintenance mechanic	Repairs, cleans and renovates equipment and machines.	Laborer
Janitor	Cleans trailers and maintains general cleaniness of site.	Laborer
Messenger	Runs errands to get equipment and meals and takes field samples to local laboratory.	Laborer
Forklift and truck driver	Operates trucks and forklifts to move equipment and materials.	Laborer
Field accountant	Maintains records of purchases made on-site.	Skilled
Instrument/electrical supervisor	Supervises and maintains electrical systems, spare parts inventory, and operates computer systems.	Highly skilled
Feed handlers	Prepares and feeds materials to the shredder for incineration.	Laborer

For instance, when burning liquid wastes with high heating values, such as hexane, a substantial fuel savings is realized. In the EPA MIS, the kiln temperature is modulated by the auxiliary fuel. The SCC is fired solely by auxiliary fuel. This is done in order to ensure better temperature control and that the DRE limits are met under field conditions with feeds having highly variable characteristics.

Rental equipment accounted for about 4.4% of the total operating cost. Equipment such as an air compressor, motor generator sets, office trailer, laboratory trailer, storage trailer, forklift and scoop-loader were all rented from local suppliers.

Filter media accounted for 3.5% of the total operating costs; the cost of the CHEAF media averaged $560.00 per day.

"Home office" support accounted for approximately 3.2% of the total operating cost, which was necessary because of the limited number and type of people in the field. Management coordination, design review, permitting, and regulatory compliance were part of home office support.

Economic Analysis

A simplified economic analysis to determine the cost per ton for processing two types of waste materials was based upon the following assumptions:

- An incineration system designed and fabricated fully utilizing the EPA MIS data and drawings
- 50% on-stream factor
- Equipment life of 15 years
- Equipment moved every 2 years on an average (Mobilization and demobilization costs incurred eight times during the equipment life). A period of 60 days is assumed for each biennial relocation. By comparison, a "transportable" incinerator would be expected to be moved once every 5 years.
- Waste Material I - lagoon sludge with heating value 3800 Btu/lb processed at $1000 \frac{\text{lb}}{\text{hr}} \times 8760 \frac{\text{hr}}{\text{yr}} \times \frac{1}{2000} \frac{\text{tons}}{\text{lb}} \times \frac{11}{12} \times 0.5 = 2000$ tons/yr
- Waste Material II - low-Btu-content soil processed at $2000 \frac{\text{lb}}{\text{hr}} \times 8760 \frac{\text{hr}}{\text{yr}} \times \frac{1}{2000} \frac{\text{tons}}{\text{lb}} \times \frac{11}{12} \times 0.5 = 4000$ tons/yr
- The mobilization and demobilization costs are assumed to be $2.0 million as per Table 12.
- Operating costs are extrapolated from the field experience based on 116 days of operation. Thus, the operating costs are calculated as $1.895 million x (365-30)/116 = $5.5 million/yr.
- Interest rates, depreciation, taxes, etc., are not considered in this simplified analysis.

The cost per ton of waste material processed in calculated as follows (using the same economic analysis approach as for the transportable incineration system; see below):

Cost/ton = (Capital Cost + 8 x Mob. & Demob. costs + 15 x Operating Costs)/
(15 x material process per year)

Costs for the two waste materials are calculated as:

Waste Material I:

$$\frac{\$5{,}100{,}000 + 8\ (\$2{,}000{,}000) + 15\ (\$5{,}500{,}000)}{15 \times 2000} = \$3400/\text{ton}$$

Waste Material II:

$$\frac{\$5{,}100{,}000 + 8\ (\$2{,}000{,}000) + 15\ (\$5{,}500{,}000)}{15 \times 4000} = \$1700/\text{ton}$$

With the proposed modifications, the revised system should:

- increase capacity by a factor of 2;
- increase the on-stream factor to 80%;
- increase the capital cost to approximately $6 million;
- increase mob./demob. costs to approximately $2.2 million;
- increase the operating costs to approximately $6.0 million/yr..

The unit cost ($/ton) expected from the modified MIS is then:

Waste Material I:

$$\frac{\$6{,}000{,}000\ +\ 8\ (\$2{,}200{,}000)\ +\ 15\ (\$6{,}000{,}000)}{15 \times 2{,}000\ \text{X2} \times 0.8/0.5} = \$1200/\text{ton}$$

Waste Material II:

$$\frac{\$6{,}000{,}000\ +\ 8\ (2{,}200{,}000)\ +\ 15\ (\$6{,}000{,}000)}{15 \times 4{,}000\ \text{X2} \times 0.8/0.5} = \$600/\text{ton}$$

COMPARISON WITH THE TRANSPORTABLE INCINERATOR

Although the EPA Mobile Incineration System has clearly demonstrated the ability to destroy liquid and solid hazardous and toxic organic wastes, its relatively low capacity severely limits its use for the massive task of cleaning up the myriad of abandoned hazardous waste sites already discovered. Since the capacity of a single mobile incineration system cannot be significantly increased without the loss of mobility, development of a modular, transportable incineration system appears to be a logical alternative. Accordingly, a project was undertaken by ORD, HWERL to examine the technical, administrative, and economic feasibility of the use of modular, transportable incineration systems for destruction of toxic organic wastes at Superfund sites in the U.S. It is expected that such a system will:

- have a capacity of 5-10 times that of the EPA Mobile Incineration System,

- be operated on a large Superfund site for a period of one to three years,

- be constructed from currently available system components.

The study addressed five major areas:

- System duty requirements, including examination of location and types of sites having incinerable wastes, and the characteristics of those wastes;

- Capabilities of existing transportable incineration systems, both domestic and foreign;

- Comparison of the treatment requirements to the capabilities of existing facilities;

- Process specifications, conceptual design, and associated capital and operating costs;

- Effects of institutional requirements, such as RCRA and State permitting regulations.

The study showed that, although a large number of Superfund sites have been identified, information on waste characteristics (types and quantities) at each site is very limited.

In lieu of an acceptable waste profile and a commercially available transportable incineration system, preliminary process engineering was performed to define the major equipment items and associated capital and operating costs for a transportable system. A waste profile was constructed with quantities and compositions of material that might typically be encountered at a land disposal or Superfund site.

A rotary kiln with a secondary combustion chamber was determined to be the most suitable type of incineration equipment for handling the broad spectrum of hazardous materials that might be present at Superfund sites. A 75 MM Btu/hr system (without the use of oxygen-enriched air; 90 MM Btu/hr with O_2 enrichment) is estimated to be the largest incineration system that can be transported without extensive field fabrication.

The major factors affecting the system economics are primary and secondary combustion chamber temperatures and the types of wastes to be processed. For a 75 MM Btu/hr system operating with 75% excess air at the exit of the secondary combustion chamber, a larger percentage of the heat input (thus more waste) can be processed in the kiln when operating at 1600-1800°F (kiln-secondary) than at 1800-2200°F (TSCA requires 2200°F for the incineration of PCBs). The higher temperature operation requires more auxiliary fuel, especially when little fuel value waste is available (as would be the case at most Superfund sites). Therefore, if PCBs or dioxins are not present or are handled separately, significant operating economies could ensue by operating at lower temperatures.

The second variable, the waste type, was found to be equally important to the overall process economics. The estimated cost for incinerating waste materials with a modular transportable system ranged from $75/ton for contaminated soil at the lower set of temperature conditions up to $480/ton for industrial solid wastes at the set of high temperature conditions. These estimates include capital and operating costs. Waste excavation, transportation, and other non-direct costs are not included.

FUTURE USE OF THE EPA MOBILE INCINERATION SYSTEM

As discussed before, Syntex may exercise an option to use the incinerator to burn approximately 800 cu yd of Springfield lagoon sludge containing 1-21 ppb dioxin and 20,000 lb of activated carbon of unknown dioxin concentration.

If Syntex does not opt to use the MIS, the system may remain at the Denney Farm site and be used to clean up other Superfund dioxin sites in southwestern Missouri.

In the event that this does not take place, the incineration system will be transported to its next operating location. The intention of EPA-sponsored operations with the MIS is more to encourage commercialization of on-site cleanup technologies than it is to use the system consistently for cleanup activities. Further use of the incineration system, after the EPA-sponsored Field Demonstration at Denney Farm, will be at the direction of the EPA Office of Solid Waste and Emergency Response. As a result of EPA experiences and operating information, the private sector will likely build improved, more reliable, larger-capacity, lower-cost systems of equivalent performance for use in routine cleanup operations.

REFERENCES

1. Yezzi, Jr., J.J., *et al.*, "Results of the Initial Trial Burn of the EPA-ORD Mobile Incineration System," Proceedings of the *1984 National Waste Processing Conference,* ASME, pp 514-534.

2. Yezzi, Jr., J.J. *et al.*, "The EPA Mobile Incineration System," Proceedings of the *1982 National Waste Processing Conference*, ASME, pp 199-212.

3. "Finding of No Significant Impact for the USEPA Mobile Incineration System at Uncontrolled Hazardous Waste Sites," Federal Register, Vol. 49, Sept. 24, 1984, pp. 37642-37644.

4. Helsel, R., *et al.*, *Laboratory Investigation of Thermal Treatment of Soil Contamination with 2, 3, 7, 8-TCDD*, IT Corporation, July 1984.

5. Mackay, D., "Environmental and Laboratory Rates of Volatilization of Toxic Chemicals from Wastes," *Hazard Assessment of Chemicals*, *Current Developments*, Vol. 1, Academic Press, Inc., 1981.

6. Dellinger, B., *et al.*, *Determination of the Thermal Stability of Selected Hazardous Organic Compounds*, USEPA, Combustion Research Facility, Jefferson, AR, 1984.

7. Lee, K.C., *et al.*, *"Revised Model for the Prediction of the Time-Temperature Requirements for Thermal Destruction of Dilute Organic Vapors and Its Usage for Predicting Compound Destructability,"* presented at the 75th Annual Meeting of the Air Pollution Control Association, New Orleans, LA, June 1982.

8. EPA, "Identification and Listing of Hazardous Waste; Mobile Incineration System," *Federal Register*, Vol. 50, No. 143, June 25, 1985, pp 30271-30274.

9. Tidball, R.R., "Geochemical Survey of Missouri, Geography of Soil Geochemistry of Missouri Agricultural Soils," *USGS Professional Paper #954-H,I*.

10. J. G. Boerngen, *et al.*, "Analytical Data for Geologic Units in Missouri and Parts of Kansas, Oklahoma and Arkansas," USGS Open File Report #75-137, 1975.

11. Memo from Frank J. Freestone to Doreen Sterling, "Delisting Petition for the EPA Mobile Incineration System: May 3, 1985." (Contains ITAS EP Toxicity Results of Uncontaminated Denney Farm Soil.)

BIBLIOGRAPHY

Bergman, A., *et al*., "Thermal Degradation of Polychlorinated Alkanes," pp 237-250, *Chemosphere*, *13*, 2, 1984.

Bridle, T. R., *et al*., "The Formation and Fate of PCDD's and PCDF's During Chlorophenol Combustion," presented at *77th Annual Meeting of the Air Pollution Control Association*, San Francisco, CA, June 24-29, 1984.

Buser, H. R., "Formation of Polychlorinated Dibenzofurans (PCDFs) and Dibenzo-p-Dioxins (PCDDs) from the Pyrolysis of Chlorobenzenes," pp 415-424, *Chemosphere*, *8*, 1979.

Buser, H. R., and H. P. Bosshardt, "Formation of Polychlorinated Dibenzofurans (PCDFs) from the Pyrolysis of PCBs," pp 109-119, Chemosphere, *1*, 1978.

Chou, S. F. J. and R. A. Griffin, *Soil, Clay, and Caustic Soda Effects on Solubility, Sorption, and Mobility of Hexachlorocyclopentadiene*, Environmental Geology Notes 104, Illinois State Geological Survey, Champaign, IL, 1983.

Cudahy, J. J., *et al*., IT Corporation, *Incineration Characteristics of RCRA Listed Hazardous Wastes*, Contract No. 68-03-2568, USEPA Industrial Research Laboratory, Cincinnati, OH July 1981.

Cudahy, J. J., *et al*., "Planning in RCRA Trial Burn, presented at *National Conference on Hazardous Waste and Environmental Emergencies*, Houston, TX, March 14, 1984.

Dellinger, B., *et al*., *Determination of the Thermal Stability of Selected Hazardous Organic Compounds*, USEPA, Combustion Research Facility, Jefferson, AR, 1984.

Duvall, D. S., *et al*., "Laboratory Characterization of the Thermal Decomposition of Hazardous Wastes," in *Land Disposal of Hazardous Wastes, Proceedings IVth Annual Research Symposium*, 1978.

Earnest, C. M., *Characterization of Smectite Clay Minerals by Differential Thermal Analysis and Thermogravimetry*, Perkin-Elmer Thermal Analysis Application Study 31, 1980.

Earnest, C. M., The Application of Differential Thermal Analysis and Thermogravimetry to the Study of Kaolinite Clay Minerals, Perkin-Elmer Thermal Analysis Application Study 20, 1980.

Ernest, C. M., "Thermal Analysis of Minerals in Coal and Coal Ash," presented at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, Atlantic City, NJ, 1981.

Eiceman, G. A., R. E. Clement, and F. W. Karasek, "Variations in Concentrations of Organic Compounds Including Polychlorinated dibenzo-p-Dioxins and Polynuclear Aromatic Hydrocarbons in Fly Ash from a Municipal Incinerator," pp 955-959, Anal. Chem., 53, 1981.

Esposito, M. P., et al., Dioxins, EPA 600/2-80-179, November 1980.

Farmer, W. J., M. S. Yang, and J. Latey, W. F. Spenser, and M. H. Roulier, "Land Disposal of Hexachlorobenzene Wastes: Controlling Vapor Movement in Soil," pp 182-190.

Flaig, W., Beutelspacher, H., Reitz, E., in "Soil Components; Organic Components," Vol. 1, Gieseking, J. E., Ed., Springer-Verlag, New York, N.Y., 1975.

Fleming, J. L., and D. M. Pitts, Draft Report Evaluation of the Capacity of the EPA Mobile Incineration System for Thermal Treatment of Contaminated Soil, Contract No. 68-0303069, USEPA, Cincinnati, OH, November 1984.

Freeman, R. A. and J. M. Schroy, "Environmental Mobility of Dioxins," presented at 8th ASTM Aquatic Symposium, Fort Mitchell, KY, April 15-17, 1984.

Giovannini, G. and S. Lucchesi, "Differential Thermal Analysis and Infrared Investigations on Soil Hydrophobic Substances," pp 457-463, Soil Science, 137, 6, June 1984.

Griffin, R. A. and E. S. K. Chian, "Attenuation of Water-Soluble Polychlorinated Biphenyls by Earth Materials," Environmental Geology Notes, November 1986.

Helling, C. S. and A. E. Krivonak, "Physiochemical Characteristics of Bound Dinitroaniline Herbicides in Soils," J. Agric. Food Chem., 26, 5, 1987.

Josephson, J., "Subsurface Organic Contaminants," pp 518A-521A, Environ. Sci. Technol., 17, 11, 1983.

Karickhoff, S. W., "Semi-Empirical estimation of Sorption of Hydrophobic Pollutants on National Sediments and Soils," pp 833-846, Chemosphere, 10 8, 1981.

Keller, W. D., "Clays," pp 190-206, Kirk-Othmer Encyclopedia of Technology, 6, 3rd ed., John Wiley & Sons, New York, 1979.

Kenaga, E. E., Predicted Bioconcentration Factors and Soil Sorption Coefficients of Pesticides and Other Chemicals, The Dow Chemical Company, Midland, MI, January 15, 1979.

Khan, S. U., Pesticides in the Soil Environment, Elsevier Scientific Publishing Company, New York, 1980.

Kooke, R. M. M., et al "Extraction Efficiencies of Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans from Fly Ash," pp 461-463, Anal. Chem., p 53, 1983.

Langer, H. G., et. al., "Thermal Chemistry of Chlorinated Phenols," in Chlorodioxins-Origin and Fate, Advances in Chemistry Series 120 Etcyl H. Blair, ed. American Chemicall Society, Washington, D.C., 1973.

Lee, K. C., et al., "Revised Model for the Prediction of the Time-Temperature Requirement for Thermal Destruction of Dilute Organic Vapors and Its Usage for Predicting Compound Destructability," presented at 75th Annual Meeting of the Air Pollution Control Association, New Orleans, LA, June 1982.

Lion, L. W., and D. Garbarini, Partitioning Equilibria of Volatile Pollutants in Three-Phase Systems, 28 pp, NTIS ADA 137202, December, 1983.

Mackay, D., "Environmental and Laboratory Rates of Volatilization of Toxic Chemical from Wastes," in Hazard Assesment of Chemicals, Current Developments, Vol. 1, Academic Press, Inc., New York, 1981.

Mitchell, B. D. and A. C. Birnie, "Biological Materials," pp 673-704, Differential Thermal Analysis, 1, 1970.

Moreale, A. and R. V. Bladel, "Adsorption and Migration of Lindane (1,2,3,4,5,6-Hexachorocyclohexane) in Soil," Parasitica, 34, 4:233-255, 1978.

Philips, C. R., Development of a Soil-Waste Interaction Matrix, Cat. No. EN 46-4/76-10, Environment Canada, Mississauga, Ontario, April 1976.

Porter, H. F. et al., "Solids Drying and Gas-Solid Systems," pp 20-121, Perry's Chemical Engineers' Handbook, 6th ed., McGraw-Hill Book Company, New York, 1984.

Rappe, C. and S. Marklund, "Formation of Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Dibenzofurans (PCDFs) by Burning or Heating Chlorophenates," pp 269-281, Chemosphere, 7, 1978.

Schnitzer, M. and I. Hoffman, "Pyrolysis of Soil Organic Matter," in Division 5-3--Soil Microbiology, Soil Science Proceedings, 1964.

Schnitzer, M. and S. U. Khan, editors, Soil Organic Matter, Elsevier Scientific Publishing Company, New York (1978).

Schroy, J. M., et al., "The Uniqueness of Dioxins? Physical/Chemical Characteristics," presented at 8th ASTM Aquatic Toxicololgy Symposium, Fort Mitchell, KY, April 15-17, 1984.

Shaub, W. M., Containment of Dioxin Emissions from Refuse Fired Thermal Processing Units-Prospects and Technical Issues, NTIS PB84-217090.

Shaub, W. M. and W. Tsang, "Dioxin Formation in Incinerators," Environ. Sci. Technol., 17 12, 1983.

Spencer, W. F., W. J. Farmer, "Assesment of the Vapor Behavoir of Toxic Organic Chemicals," presented at American Chemical Society Meeting, Miami, FL, September 10-15, 1978.

Spencer, W. F., W. J. Farmer, and M. M. Cliath, Pesticide Volatilization, 47 pp, Agricultural Research Service, U.S. Department of Agriculture, 1973.

Stehl, R. H., et al., "The Stability of Pentachlorophenol and Chlorinated Dioxins to Sunlight, Heat, and Combustion," in Chlorodioxins - Origin and Fate, Advances in Chemistry Series 120, Etcyl H. Blair, ed., American Chemical Society, Washington, D.C., 1973.

Thibodeaux, L.J., Chemodynamics-Environmental Movement of Chemicals in Air, Water, and Soil, John Wiley & Sons, New York, 1979.

Thibodeaux, L. J., "Estimation of the Air Emissions from Hazardous Waste Landfills," presented at 72nd American Institute of Chemical Engineers Annual Meeting, San Francisco, CA., August 1979.

Treybal, R. E., Mass-Transfer Operations, 2nd ed., McGraw-Hill Book Company, New York (1968).

Versar, Inc., Draft Report Physical - Chemical properties and Categorization of RCRA Wastes According to Volatility, 93 pp, Contract No. 68-03-3041, USEPA, Cincinnati, OH, April 30, 1984.

Wong, T.S., "Dioxin Formation and Destruction in Combustion Processes," presented at 77th Annual Meeting of the Air Pollution Control Association, San Francisco, CA, June 24-29, 1984.

APPENDIX A

DIOXIN TRIAL BURN RESULTS SUMMARIES
(EXCERPTED FROM TRIAL BURN REPORT)

TABLE 2. INCINERATION SYSTEM OPERATING CONDITIONS SUMMARY

Parameter	Test 2 Average				Test 3 Average
	Run #2	Run #3	Run #4	Run #5	Runs 1, 2, & 3
Rotary Kiln					
Outlet gas temperature (deg. F)	1,650	1,600	1,678	1,729	1,587
Pressure (in. H2O vacuum)	0.7	0.3	0.2	0.3	0.1
Combustion air flow (scfm)	1,029	923	1,177	1,056	1,098
Atomization air flow (scfm)	79	89	90	89	90
Diesel fuel flow (lb/hr)	104	45	106	45	60
Liquid waste flow (lb/hr)	233	236	234	247	0
Solid waste flow (lb/hr)	1,158	1,363	2,068	1,322	973
Ash discharge rate (lb/hr)	933	989	1,531	1,105	463
Gas residence time (sec) *	2.21	2.99	2.05	2.35	2.36
Excess air level (%) *	59	48	43	49	62
Secondary Combustion Chamber					
Outlet gas temperature (deg. F)	2,178	2,190	2,187	2,196	2,172
Pressure (in. H2O vacuum)	0.8	0.4	0.7	0.8	0.7
Combustion air flow (scfm)	857	717	758	932	1,041
Diesel fuel flow (lb/hr)	211	178	202	238	251
Gas residence time (sec) *	2.49	3.18	2.49	2.55	2.37
Oxygen (vol. %)	7.70	6.97	6.44	6.42	7.55
Carbon dioxide (vol. %)	10.9	11.3	11.4	11.1	11.0
Carbon monoxide (vol. ppm)	4.1	2.0	2.3	2.5	3.5
Quench System					
Process liquor pH	8.7	8.9	8.6	8.3	8
Quench recycle flow (gal/min)	45	46	41	50	54
Makeup water flow (gal/min)	12	7	9	9	12
CHEAF					
Process liquor pH	8.6	9	9.8	9.1	8.8
CHEAF recycle flow (gal/min)	17	9	13	13	15
Pressure differential (in. H2O)	19	13	15	16	16
MX Scrubber					
Process liquor pH	8.7	8.5	8.6	8.7	8.6
MX recycle flow (gal/min)	127	171	163	161	145
Stack					
Temperature (deg. F)	164	168	179	171	173
Pressure (in. H2O)	+ 0.62	+ 0.59	+ 0.59	+ 0.59	+ 0.54
Gas flow rate (dscfm)	3,649	2,876	3,167	3,299	3,361

* Combustion gas retention time and excess air levels calculated by material balance

TABLE 3. RCRA/MDNR COMPLIANCE SUMMARY

Parameter	Required Level	Test 2 Run #2	 Run #3	 Run #4	 Run #5	Test 3 Combined
Operating Standards						
Rotary kiln temperature (deg. F)	) 1,400	1,553	1,519	1,655	1,685	1,566
	(1,900	1,725	1,673	1,741	1,758	1,619
Rotary kiln vacuum (in. H2O)	) 0	0.5	0.1	0.1	0.2	0.1
SCC temperature (deg. F)	) 2,050	2,107	2,190	2,182	2,190	2,169
	(2,400	2,240	2,190	2,190	2,238	2,174
SCC gas flow (acfm)	14,500	12,785	10,019	12,811	12,480	13,463
	1,450					
SCC oxygen (vol. %)	) 4	6.37	4.74	5.46	4.29	5.40
SCC carbon monoxide (vol. ppm)	(100 (6 min.)	* 282	3.9	4.0	16.1	6.8
Quench recycle flow (gal/min)	) 40	44	45	33	47	52
CHEAF recycle flow (gal/min)	) 8	15	8	11	12	12
MX scrubber flow (gal/min)	) 100	127	[illegible]	162	156	156
MX scrubber pH	) 8.5	8.6	[illegible]	8.5	8.6	8.6
ID fan inlet vacuum (in. H2O)	) 25	27	30	31	32	34
Waste Feed Characteristics						
Liquid waste feed						
total flow (lb/hr)		233	236	234	247	
2,3,7,8-TCDD conc. (ppm)	(400	249	357	264	225	
2,3,7,8-TCDD feed rate (g/hr)	(27.2	26.3	38.3	28.0	25.2	
Solid waste feed						
total flow (lb/hr)	(2,000	1,158	1,363	2,068	1,322	973
2,3,7,8-TCDD conc. (ppb)		101	382	1010	770	
2,3,7,8-TCDD feed rate (g/hr)		0.05	0.24	0.95	0.46	
Performance Standards - Stack						
DRE for 2,3,7,8-TCDD						
emission rate (mg/day)		(0.169	(0.127	(0.031	(0.064	
DRE (%)	) 99.9999	99.99997	99.99998	99.99999	99.99998	
Bromine emissions						
emission rate (kg/hr)						(0.12
removal efficiency (%)						) 99.0
Particulate matter						
emission rate (mg/m^3 @ 7% O2)	(180	134.3	147.3	145.6	201.5	

* Combustion gas flowrate calculated by material balance.

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Table 4. TEST 2 LIQUIDS & SOLIDS FEED CHARACTERISTICS SUMMARY

Analysis Parameter (units)	Fuel Oil				Waste Liquid				Waste Solids				Makeup Water				Alkaline Solution			
	Run #2	Run #3	Run #4	Run #5	Run #2	Run #3	Run #4	Run #5	Run #2	Run #3	Run #4	Run #5	Run #2	Run #3	Run #4	Run #5	Run #2	Run #3	Run #4	Run #5
ITAS Sample Number	B2898	B4619	B4645	B4678	B2889/90	B4623	B4637/59	B4680/98	B2902	B4622	B4672	B4697	B2893	B4616	B4646	B4679	B2901	B4618	B4647	B4681
Feed Rates (lb/hr) *	315	223	308	283	233	236	234	247	1,158	1,363	2,068	1,322	6,003	3,502	4,502	4,502	489	894	2,223	857
Density (g/cc)		0.856	0.862	0.856	0.973	0.867	0.864	0.861		1.24	1.31	1.28					1.094	1.107	1.092	1.084
Heating Value (BTU/lb)	19,499	19,383	19,412	19,336	11,256	11,445	11,315	13,312		90	95	82								
Elemental- Carbon (wt %)	87.64	86.43	86.56	86.37	50.32	51.32	51.11	67.86		2.46	1.32	0.88								
- Hydrogen (wt %)	12.17	12.46	12.6	12.82	9.91	9.78	9.64	9.01		1.00	1.29	1.26								
- Nitrogen (wt %)	0.013	0.035	0.02	0.027	0.012	0.012	0.013	0.05		0.027	0.033	0.038								
- Oxygen (wt %)	< 0.5	0.55	< 0.5	< 0.5	24.61	23.39	23.85	10.99		7.19	4.07	2.59								
- Chlorine (wt %)	11 ppm	0.004	0.005	0.005	14.9	13.75	13.23	11.89		0.14	0.23	0.15								
- Sulfur (wt %)	0.30	0.25	0.018	0.27	0.17	0.019	1.06	0.015		0.14	0.14	0.052								
Ash Content (wt.%)						4.10	3.00	0.85		90.28	93.76	95.23								
Moisture (wt %)						6.48	6.39	2.35		5.94	9.28	9.12								
POHC	ppb	pph	ppb	ppb	ppm	ppm	ppm	ppm	ppb	ppb	ppb	ppb	ppt	ppt	ppt	ppt	ppt	ppt	ppt	ppt
2,3,7,8-TCDD	ND(0.11)	ND(1.7)	ND(5.5)	ND(1.8)	249	357	264	225	101	382	1,010	770	ND(2.0)	0.55	ND(4.0)	ND(1.0)	ND(2.0)	0.75	ND(1.4)	ND(1.0)
Other PCDD/PCDF Cogeners	ppb	ppb	ppb	ppb	ppm	ppm	ppm	ppm	ppb	ppb	ppb	ppb	ppt	ppt	ppt	ppt	ppt	ppt	ppt	ppt
TCDD	ND(0.52)	ND(2.5)	ND(1.2)	ND(0.89)	217	240	192	143	45.3	274	590	516	ND(0.65)	0.68	ND(1.9)	ND(0.41)	ND(0.81)	0.84	ND(0.81)	ND(1.3)
TCDF	ND(1.7)	ND(5.0)	ND(6.1)	ND(3.3)	12	ND(32)	ND(5.8)	ND(4.5)	17	33	82	45	ND(1.8)	ND(0.52)	ND(0.37)	ND(1.9)	ND(3.4)	ND(0.39)	ND(1.6)	ND(0.62)
PCDD	ND(2.9)	ND(1.2)	ND(1.1)	ND(0.86)	ND(21)	ND(7.0)	ND(18)	ND(6.2)	3.6	ND(0.43)	ND(0.50)	ND(0.38)	ND(2.0)	ND(0.68)	ND(0.29)	ND(0.59)	ND(0.87)	ND(0.83)	ND(1.0)	ND(0.32)
PCDF	ND(0.31)	ND(1.5)	ND(0.65)	ND(0.63)	ND(3.1)	ND(8.6)	ND(3.2)	ND(7.0)	ND(0.52)	ND(0.18)	ND(0.76)	ND(0.26)	ND(2.8)	ND(0.29)	ND(0.23)	ND(0.61)	ND(2.3)	ND(1.1)	ND(1.3)	ND(1.2)
HxCDD	ND(1.6)	ND(2.5)	ND(1.7)	ND(0.93)	ND(70)	ND(0.96)	ND(0.76)	ND(1.1)	ND(0.078)	ND(0.34)	ND(0.37)	ND(0.67)	ND(6.2)	ND(0.87)	ND(0.66)	ND(0.36)	ND(1.5)	ND(2.3)	ND(1.6)	ND(0.48)
HxCDF	ND(2.2)	ND(1.9)	ND(3.6)	ND(4.6)	ND(14)	ND(1.3)	ND(3.0)	ND(9.2)	ND(0.12)	ND(0.19)	ND(1.5)	ND(1.5)	ND(4.2)	ND(0.49)	ND(0.63)	ND(0.34)	ND(4.7)	ND(1.2)	ND(0.87)	ND(0.33)
HpCDD	ND(1.4)	ND(0.05)	ND(0.35)	ND(0.91)	ND(1.9)	ND(0.58)	ND(4.9)	ND(1.7)	0.17	ND(1.6)	ND(2.0)	ND(2.2)	ND(0.85)	ND(0.15)	ND(0.09)	ND(0.16)	ND(0.28)	ND(0.19)	ND(0.09)	ND(0.19)
HpCDF	ND(0.55)	ND(1.2)	ND(1.2)	ND(1.3)	ND(11)	ND(29)	ND(0.72)	ND(5.4)	ND(0.33)	ND(0.68)	ND(1.0)	ND(1.6)	ND(1.6)	ND(1.6)	ND(0.07)	ND(0.71)	ND(1.1)	ND(0.60)	ND(0.92)	ND(1.2)
OCDD	ND(1.1)	ND(0.47)	ND(0.55)	ND(0.26)	ND(0.96)	ND(2.2)	ND(1.1)	ND(0.70)	18.3	17	16	15	ND(0.45)	ND(0.60)	ND(0.14)	ND(0.12)	ND(0.36)	ND(0.71)	ND(0.28)	ND(0.23)
OCDF	ND(0.74)	ND(3.8)	ND(0.12)	ND(0.20)	ND(2.5)	ND(3.7)	ND(0.32)	ND(0.58)	ND(0.19)	ND(0.43)	ND(0.79)	ND(0.39)	ND(036)	ND(0.30)	ND(0.04)	ND(0.07)	ND(0.57)	ND(0.06)	0.44	ND(0.30)

NOTE: Analyses showing dual sample numbers (ie. B4680/98) are reported in this table as the average of two analyses.

* Waste solids feed rate based on weights of drums fed to incinerator during test runs.

Table 5. TEST 2 LIQUID & SOLID DISCHARGES

Analysis Parameter (units)		Kiln Ash				CHEAF				Purge Water			
		Run #2	Run #3	Run #4	Run #5	Run #2	Run #3	Run #4	Run #5	Run #2	Run #3	Run #4	Run #5
ITAS Sample Number		B2913	B4621	B4660	B4701	B2909	B4620	B4650	B4699	B2892	B4615	B4649	B4691
Discharge Rate (lb/hr)	*	933	989	1,531	1,105	22	24	21	22	2,177	1,905	2,236	1,973
POHC		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppt	ppt	ppt	ppt
2,3,7,8-TCDD		ND(0.20)	ND(0.08)	ND(0.10)	ND(0.04)	ND(0.25)	ND(0.05)	ND(0.08)	ND(0.09)	ND(3.0)	ND(0.08)	ND(0.2)	ND(0.40)
Other PCDD/PCDF Cogeners:		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppt	ppt	ppt	ppt
TCDD		ND(0.06)	ND(0.06)	ND(0.07)	ND(0.09)	ND(0.06)	ND(0.03)	ND(0.06)	ND(0.12)	ND(9.2)	ND(1.0)	ND(1.3)	ND(0.20)
TCDF		ND(0.028)	ND(0.31)	ND(0.24)	ND(0.02)	ND(0.056)	ND(0.08)	ND(0.02)	ND(0.12)	ND(3.4)	ND(1.1)	ND(0.97)	ND(2.0)
PCDD		ND(0.03)	ND(0.13)	ND(0.09)	ND(0.02)	ND(0.03)	ND(0.01)	ND(0.02)	ND(0.03)	ND(1.7)	ND(0.97)	ND(0.71)	ND(0.52)
PCDF		ND(0.069)	ND(0.02)	ND(0.29)	ND(0.08)	ND(0.15)	ND(0.04)	ND(0.04)	ND(0.04)	ND(1.9)	ND(0.32)	ND(0.29)	ND(1.3)
HxCDD		ND(0.18)	ND(0.13)	ND(0.14)	ND(0.14)	ND(0.10)	ND(0.03)	ND(0.03)	ND(0.13)	ND(5.5)	ND(1.2)	ND(0.85)	ND(0.91)
HxCDF		ND(0.28)	ND(0.03)	ND(0.20)	ND(0.02)	ND(0.30)	ND(0.05)	ND(0.08)	ND(0.05)	ND(5.4)	ND(0.51)	ND(1.1)	ND(1.0)
HpCDD		ND(0.08)	ND(0.02)	ND(0.01)	ND(0.08)	ND(0.027)	ND(0.01)	ND(0.004)	ND(0.01)	ND(0.36)	ND(0.11)	ND(0.08)	ND(0.05)
HpCDF		ND(0.27)	ND(0.02)	ND(0.14)	ND(0.17)	ND(0.077)	ND(0.07)	ND(0.08)	ND(0.05)	ND(3.1)	ND(0.98)	ND(1.0)	ND(0.84)
OCDD		0.22	ND(0.09)	ND(0.10)	ND(0.04)	0.09	0.05	ND(0.05)	ND(0.06)	ND(1.0)	ND(0.77)	ND(0.60)	ND(0.17)
OCDF		ND(0.024)	ND(0.05)	ND(0.02)	ND(0.02)	ND(0.033)	ND(0.01)	ND(0.006)	0.04	ND(0.85)	ND(0.06)	ND(0.03)	ND(0.16)

* Kiln ash and CHEAF filter discharge weights based on weghts measured during test runs.

Table 6. TEST 2 STACK GAS MODIFIED METHOD 5 (MM5) DATA

Parameter (units)	Probe Rinse & Filter				Condenser & Impinger Water				Florisil Resin				IAD Resin			
	Run 02	Run 03	Run 04	Run 05	Run 02	Run 03	Run 04	Run 05	Run 02	Run 03	Run 04	Run 05	Run 02	Run 03	Run 04	Run 05
ITAS Sample Number	B2947	B4631	B4653	B4684	B2899	B4617	B4652	B4686	B2894	B4625	B4639	B4673	B2895	B4626	B4640	B4674
Particulate Residue (mg)	457.5	384.6	472.5	625.3												
POHC - 2,3,7,8-TCDD						ppt		ppt								
Quantity measured (ng/sample)	ND(1.9)	4.6	ND(0.80)	ND(0.90)	ND(3.1)	ND(0.4)	ND(2.0)	ND(9.0)	ND(3.2)	ND(0.79)	ND(4.0)	ND(1.0)	ND(0.57)	ND(1.0)	ND(2.0)	ND(1.0)
Other PCDD/PCDF Cogeners:																
TCDD (ng/sample)	ND(3.6)												ND(0.99)	ND(1.1)	ND(0.82)	ND(3.9)
TCDF (ng/sample)	ND(6.4)												ND(0.96)	ND(0.50)	ND(0.83)	ND(1.5)
PCDD (ng/sample)	ND(5.1)												ND(0.35)	ND(0.29)	ND(0.52)	ND(4.7)
PCDF (ng/sample)	ND(3.2)												ND(2.0)	ND(0.54)	ND(1.2)	ND(1.9)
HxCDD (ng/sample)	ND(10.0)												ND(2.3)	ND(0.42)	ND(0.71)	ND(1.3)
HxCDF (ng/sample)	ND(3.3)												ND(3.5)	ND(0.28)	ND(0.53)	ND(0.85)
HpCDD (ng/sample)	ND(1.3)												ND(0.42)	ND(0.05)	ND(0.13)	ND(1.1)
HpCDF (ng/sample)	ND(6.1)												ND(0.87)	ND(0.06)	ND(1.0)	ND(1.2)
OCDD (ng/sample)	2.2												1.7	ND(0.23)	ND(0.19)	2.2
OCDF (ng/sample)	ND(1.0)												ND(0.29)	ND(0.05)	ND(0.04)	ND(0.84)

Table 7. TEST 2 STACK GAS SUMMARY

Parameter (units)	MM5 Train Composite Run #2	Run #3	Run #4	Run #5	Stack Gas Run #2	Run #3	Run #4	Run #5
ITRS Sample Number	B2899	B4617	B4652	B4686				
Stack Gas Flow (dscm/min)					103.3	81.4	89.7	93.4
Stack Gas Composition								
Orsat Oxygen (vol. %)					10.2	11.1	10.1	10.8
Monitor Oxygen (vol. %)					11.2	11.7	10.9	11.4
Orsat Carbon Dioxide (vol. %)					7.89	7.13	7.64	7.66
Monitor Carbon Dioxide (vol. %)					8.14	7.21	7.85	8.06
Monitor NOx (vol. ppm)					134	85	93	97
Sample Volume (dscm)					4.42	3.68	4.18	4.24
Particulate Matter								
Quantity measured (mg)	457.5	384.6	472.5	625.3				
Concentration (mg/m^3 @ 7% O2)					134.3	147.3	145.6	201.5
Emission Rate (g/hr)					642.2	510.9	608.4	826.1
POHC - 2,3,7,8-TCDD								
Quantity measured (ng/sample)	ND(5.0)	ND(4.0)	ND(1.0)	ND(2.0)				
Concentration (ng/m^3)					(1.13	(1.09	(0.24	(0.47
Emission rate (mg/day)					(0.169	(0.127	(0.031	(0.064
Other PCDD/PCDF Cogeners:								
TCDD (ng/sample)		ND(3.9)	ND(1.7)	ND(2.4)				
TCDF (ng/sample)		ND(4.9)	ND(9.8)	ND(6.3)				
PCDD (ng/sample)		ND(3.3)	ND(3.1)	ND(1.9)				
PCDF (ng/sample)		ND(5.2)	ND(3.1)	ND(1.7)				
HxCDD (ng/sample)		ND(2.6)	ND(7.6)	ND(2.3)				
HxCDF (ng/sample)		ND(0.48)	ND(3.8)	ND(2.5)				
HpCDD (ng/sample)		ND(6.6)	ND(4.6)	ND(7.7)				
HpCDF (ng/sample)		ND(3.2)	ND(6.5)	ND(6.0)				
OCDD (ng/sample)		25	8.7	57.6				
OCDF (ng/sample)		ND(3.0)	ND(1.2)	ND(5.9)				

Table 8. TEST 2 OPERATING CONDITIONS SUMMARY

ROTARY KILN AND SECONDARY COMBUSTION CHAMBER

Operating	Test Minimum				Test Maximum				Test Average			
Parameter (units)	Run 82	Run 83	Run 84	Run 85	Run 82	Run 83	Run 84	Run 85	Run 82	Run 83	Run 84	Run 85
Ambient Temperature (deg. F)	72	63	69	62	79	70	76	75	74	68	73	68
Kiln Comb. Air Flow (SCFM)	949	921	1,160	1,051	1,144	943	1,182	1,073	1,029	923	1,177	1,056
Kiln Comb. Air Temp. (deg. F)	92	86	91	84	97	94	99	94	94	90	95	90
Kiln Blower Pressure (in. H2O)	28	29	29	30	29	30	30	31	28	29	29	30
Burner 1 Fuel Flow (gal/hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burner 2 Fuel Flow (gal/hr)	12.1	5.9	14.2	5.9	16.7	6.9	15.2	6.9	14.6	6.3	14.8	6.3
Waste Oil Flow Rate (lb/hr)	226	232	229	239	238	245	240	275	233	236	234	247
Waste Solids Flow Rate (lbs/hr)	463	437	1,843	483	1,628	2,427	2,445	2,093	1,329	1,354	2,187	1,443
Kiln Temperature (deg. F)	1,553	1,519	1,635	1,685	1,725	1,673	1,741	1,758	1,650	1,600	1,678	1,729
Kiln Vacuum (in. H2O)	0.5	0.1	0.1	0.2	1.1	0.4	0.5	0.8	0.7	0.3	0.2	0.3
Kiln Water Flow (gal/min)	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	.0	0.0	0.0	0.0
Water Atom. Pressure (psi)	20	20	20	20	20	20	20	26	20	20	20	21
Kiln Drive Flow (gal/min)	1.0	1.1	1.1	1.2	1.0	1.1	1.2	1.2	1.0	1.1	1.1	1.2
SCC Comb. Air Flow (SCFM)	780	689	689	897	920	731	814	959	857	717	758	932
SCC Comb. Air Temp. (deg. F)	94	97	98	90	102	104	104	103	97	100	101	98
SCC Blower Press. (in. H2O)	22	21	21	21	22	21	22	22	22	21	21	21
Burner 3 Fuel Flow (gal/hr)	11.6	11.6	13.5	15.5	14.8	13.1	14.5	17.4	13.1	12.3	13.9	16.8
Burner 4 Fuel Flow (gal/hr)	15.2	10.9	12.8	15.7	18.1	13.7	14.7	19.5	16.5	12.7	14.2	16.5
SCC Temperature (deg. F)	2,107	2,190	2,182	2,190	2,240	2,190	2,190	2,238	2,178	2,190	2,187	2,196
SCC Vacuum (in. H2O)	0.6	0.3	0.4	0.7	1.1	0.5	0.8	1.2	0.8	0.4	0.7	0.8
SCC Gas Flow - Venturi (SCFM)		10,074	11,234	11,698		10,538	13,206	13,670	12,785	10,345	12,136	12,510
SCC Oxygen - GC (vol. %)	6.37	5.64	6.23	7.48	9.18	8.50	6.78	8.26	7.70	6.97	6.53	7.78
SCC Oxygen - Polar. (vol. %)	6.81	4.74	5.46	4.29	9.09	8.94	8.28	8.83	7.96	6.61	6.44	6.42
SCC Carbon Dioxide (vol. %)	9.11	10.0	11.1	10.8	12.0	12.6	11.7	11.4	10.9	11.3	11.4	11.1
SCC Carbon Monoxide - GC (vol. ppm)	1.9	1.4	1.6	3.6	104	3.2	2.1	4.2	4.1	2.0	1.9	3.8
SCC Carbon Monoxide - NDIR (vol. ppm)	1.3	0.0	1.2	0	282	3.9	4.0	16.1	7.7	1.3	2.3	2.5
SCC Total Hydrocarbons (vol. ppm)	0.1	0.5	0.5	0.9	1.5	1.9	0.6	0.9	0.1	0.5	0.5	0.9
SCC Oxides of Nitrogen (vol. ppm)	126	81	99	162	147	141	134	175	139	132	126	166

AIR POLLUTION CONTROL EQUIPMENT

Operating	Test Minimum				Test Maximum				Test Average			
Parameter (units)	Run 82	Run 83	Run 84	Run 85	Run 82	Run 83	Run 84	Run 85	Run 82	Run 83	Run 84	Run 85
Quench Recycle Flow (gal/min)	44	45	33	47	45	46	47	51	45	46	41	50
Quenched Gas Temperature (deg. F)	190	200	175	175	260	225	250	200	229	213	216	185
Quench Water pH	7.3	8.7	7.9	8.1	9.4	9.1	9.3	8.7	8.7	8.9	8.6	8.3
Makeup Water Flow (gal/min)	10	7	7	8	12	7	12	15	12	7	9	9
CHEAF Exit Temperature (deg. F)	160	165	170	165	168	168	170	170	166	165	170	169
CHEAF Water Flow (gal/min)	15	8	11	12	18	10	14	15	17	9	13	13
CHEAF Filter Differential (in. H2O)	19	13	12	15	20	14	18	17	19	13	15	16
CHEAF Inlet Vacuum (in. H2O)	4.5	5.5	3.5	3.0	5.0	6.5	4.0	3.5	4.7	6.1	3.6	3.3
CHEAF Water pH	8.3	8.9	9.5	8.9	9.2	9.1	9.9	9.1	8.6	9.0	9.8	9.1
MX Scrubber Water Flow (gal/min)	127	167	162	156	127	173	171	162	127	171	163	161
MX Scrubber Water pH	8.6	8.3	8.5	8.6	8.8	8.6	8.6	8.7	8.7	8.5	8.6	8.7
ID Fan Inlet Vacuum (in. H2O)	27	30	31	32	28	31	33	34	28	31	32	33
ID Fan Vibration (mil)	0.6	0.7	0.8	0.8	0.9	1.0	0.9	1.0	0.7	0.8	0.9	1.0
ID Fan Drive Speed (RPM)	1,700	1,700	1,750	1,750	1,725	1,700	1,800	1,825	1,708	1,700	1,794	1,798
Stack Temperature (deg. F)	184	170	180	176	188	178	185	180	187	175	182	178

TABLE 9. TEST 3 FEED AND DISCHARGE SUMMARY

Parameter	Solids Feed Composite	Kiln Ash Composite	Purge Water Composite	CHEAF Composite	Stack Gas Run #1	Stack Gas Run #2	Stack Gas Run #3
ITAS Sample Number	B4704	B4716	B4703	B4705	B4706	B4707	B4708
Feed Rate (lb/hr) *	973						
Discharge Rate (lb/hr) *		463	1,633	22			
Stack Gas							
Sample volume (dscm)					0.439	0.435	0.412
Flow rate (dscm/min)					95.2	95.2	95.2
Organic Bromide							
Concentration (%)	2.78						
Feed rate (kg/hr)	12.3						
Inorganic Bromide							
Concentration (%)	0.08						
Feed rate (kg/hr)	0.35						
Total Bromide							
Concentration (%)		1.16	1.08	0.48	(10 ppm	(10 ppm	(10 ppm
Discharge rate (kg/hr)		2.44	8.01	0.05	(107	(127	(126
Total Chloride							
Concentration (%)					(0.01	(0.01	(0.01
Discharge rate (g/hr)					(1,070	(1,270	(1,260

* Waste solid feed rate and kiln ash dicharge rate based on weights measured during test run.

Table 10. TEST 3 OPERATING CONDITIONS SUMMARY

ROTARY KILN AND SECONDARY COMBUSTION CHAMBER

Operating Parameter (units)	Test Minimum	Test Maximum	Test Average
Ambient Temperature (deg. F)	70	76	74
Kiln Comb. Air Flow (SCFM)	1,090	1,114	1,098
Kiln Comb. Air Temp. (deg. F)	96	98	97
Kiln Blower Pressure (in. H2O)	29	30	29
Burner 1 Fuel Flow (gal/hr)	0.0	0.0	0.0
Burner 2 Fuel Flow (gal/hr)	6.1	6.1	6.1
Diesel Oil Flow Rate (lb/hr)	0	30	19
Waste Solids Flow Rate (lbs/hr)	675	1,119	863
Kiln Temperature (deg. F)	1,566	1,619	1,587
Kiln Vacuum (in. H2O)	0.1	0.2	0.1
Kiln Water Flow (gal/min)	0.0	0.0	0.0
Water Atom. Pressure (psi)	20	20	20
Kiln Drive Flow (gal/min)	1.2	1.2	1.2
SCC Comb. Air Flow (SCFM)	1,034	1,056	1,041
SCC Comb. Air Temp. (deg. F)	102	103	102
SCC Blower Press. (in. H2O)	21	21	21
Burner 3 Fuel Flow (gal/hr)	17.2	18.1	17.5
Burner 4 Fuel Flow (gal/hr)	17.4	18.4	17.7
SCC Temperature (deg. F)	2,169	2,174	2,172
SCC Vacuum (in. H2O)	0.6	0.8	0.7
Total SCC Gas Flow (SCFM)	14,327	14,426	14,393
SCC Oxygen - GC (vol. %)	6.49	9.24	7.55
SCC Oxygen - Polar. (vol. %)	5.40	8.39	7.27
SCC Carbon Dioxide (vol. %)	9.8	12.0	11.0
SCC Carbon Monoxide - GC (vol. ppm)	3.1	3.7	3.5
SCC Carbon Monoxide - NDIR (vol. ppm)	1.6	6.8	3.2
SCC Total Hydrocarbons (vol. ppm)	0.8	0.8	0.8
SCC Oxides of Nitrogen (vol. ppm)	143	168	156

AIR POLLUTION CONTROL EQUIPMENT

Operating Parameter (units)	Test Minimum	Test Maximum	Test Average
Quench Recycle Flow (gal/min)	52	55	54
Quenched Gas Temperature (deg. F)	200	225	217
Quench Water pH	8.1	8.1	8.0
Makeup Water Flow (gal/min)	12	13	12
CHEAF Exit Temperature (deg. F)	168	168	168
CHEAF Water Flow (gal/min)	12	15	15
CHEAF Filter Differential (in. H2O)	16	17	16
CHEAF Inlet Pressure (in. H2O)	3.0	3.0	3.0
CHEAF Water pH	8.8	8.8	8.8
MX Scrubber Water Flow (gal/min)	156	145	145
MX Scrubber Water pH	8.6	8.6	8.6
ID Fan Inlet Pressure (in. H2O)	34	34	34
ID Fan Vibration (mil)	1.0	1.0	1.0
ID Fan Drive Speed (RPM)	1,800	1,800	1,800
Stack Temperature (deg. F)	178	180	179

TABLE 21. TEST 2-2 CONTINUOUS EMISSION MONITOR RESULTS SUMMARY

Parameter	Raw Data						Calibration Coefficients		Corrected Data		
	Test Minimum	Test Maximum	Test Average	Test Std. Dev.	Test Variance	No. Data Points	Slope	Intercept	Test Minimum	Test Maximum	Test Average
Stream 1/ O2 %	6.28	9.04	7.59	0.9	0.7	69	1.02	-0.03	6.37	9.18	7.70
CO2 %	8.97	11.9	10.8	0.7	0.5	69	1.01	0.03	9.11	12.0	10.9
CO ppm	1.5	134	4.4	15.8	249.9	69	0.77	0.73	1.9	104	4.1
THC ppm	0.0	1.6	.0	0.2	.0	69	0.92	0.07	0.1	1.5	0.1
NOx ppm	125	146	138	4.6	21.4	69	1.01	0.00	126	147	139
Stream 2/ O2 %	8.21	13.5	11.0	0.8	0.6	69	1.04	-0.30	8.25	13.8	11.2
CO2 %	6.03	10.5	8.03	0.7	0.4	69	1.03	-0.13	6.08	10.7	8.14
CO ppm	1.7	3.5	2.1	0.3	0.1	69	0.72	1.32	2.5	3.9	2.9
THC ppm	0.0	0.0	0.0	0.0	0.0	69	0.78	1.45	1.5	1.5	1.5
NOx ppm	125	186	137	7.5	56.7	69	0.99	-1.41	122	182	134
Stream 3/ O2 %	6.95	9.80	8.01	0.9	0.7	57	1.08	-0.69	6.81	9.89	7.96
CO ppm	1.6	250	7.3	32.4	1049.5	57	1.13	-0.59	1.3	282	7.7

TABLE 22. TEST 2-3 CONTINUOUS EMISSION MONITOR RESULTS SUMMARY

Parameter	Raw Data Test Minimum	Test Maximum	Test Average	Test Std. Dev.	Test Variance	No. Data Points	Calibration Coefficients Slope	Intercept	Corrected Data Test Minimum	Test Maximum	Test Average
Stream 1/ O2 %	5.67	8.42	6.96	0.8	0.6	46	1.040	-0.260	5.64	8.50	6.97
CO2 %	10.1	12.7	11.4	0.7	0.5	46	0.987	0.025	10.0	12.6	11.3
CO ppm	0.7	2.6	1.4	0.4	0.2	46	0.931	0.758	1.4	3.2	2.0
THC ppm	0.0	1.5	.0	0.2	.0	46	0.920	0.482	0.5	1.9	0.5
NOx ppm	88	153	143	10.4	108.1	46	0.934	-1.573	81	141	132
Stream 2/ O2 %	10.7	12.8	11.7	0.6	0.3	86	1.021	-0.223	10.7	12.8	11.7
CO2 %	6.46	8.05	7.22	0.4	0.1	86	0.998	0.005	6.45	8.04	7.21
CO ppm	0.0	2.4	1.4	0.3	0.1	86	0.935	0.334	0.3	2.6	1.6
THC ppm	0.3	0.5	0.4	.0	.0	86	0.917	0.300	0.6	0.8	0.7
NOx ppm	81	97	88	4.6	21.2	86	0.972	-0.817	78	93	85
Stream 3/ O2 %	4.83	8.99	6.68	1.0	1.0	67	1.008	-0.124	4.74	8.94	6.61
CO ppm	0.4	4.3	1.7	0.7	0.5	67	1.005	-0.440	.0	3.9	1.3

TABLE 23. TEST 2-4 CONTINUOUS EMISSION MONITOR RESULTS SUMMARY

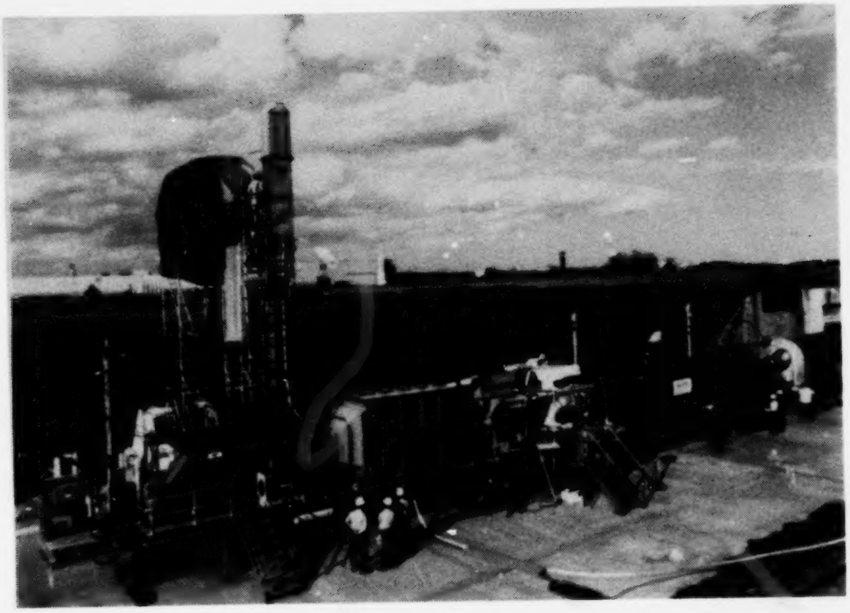
Parameter	Raw Data						Calibration Coefficients		Corrected Data		
	Test Minimum	Test Maximum	Test Average	Test Std. Dev.	Test Variance	No. Data Points	Slope	Intercept	Test Minimum	Test Maximum	Test Average
Stream 1/ O_2 %	6.37	6.91	6.67	0.2	.0	9	1.016	-0.242	6.23	6.78	6.53
CO_2 %	11.2	11.8	11.5	0.2	.0	9	0.995	-0.041	11.1	11.7	11.4
CO ppm	1.3	1.9	1.7	0.2	.0	9	0.928	0.354	1.6	2.1	1.9
THC ppm	0.0	0.2	.0	0.1	.0	9	0.881	0.461	0.5	0.6	0.5
NO_x ppm	109	148	138	10.8	116.6	9	0.900	1.171	99	134	126
Stream 2/ O_2 %	10.2	12.1	11.1	0.4	0.1	104	1.006	-0.216	10.0	12.0	10.9
CO_2 %	7.14	8.43	7.91	0.2	0.1	104	0.993	-0.002	7.09	8.37	7.85
CO ppm	0.3	5.6	1.1	0.6	0.4	104	0.890	0.469	0.7	5.5	1.5
THC ppm	0.0	1.2	0.1	0.1	.0	104	0.839	0.736	0.7	1.7	0.9
NO_x ppm	90	100	94	2.1	4.6	103	0.994	-0.028	89	99	93
Stream 3/ O_2 %	5.55	8.33	6.52	0.6	0.4	40	1.014	-0.169	5.46	8.28	6.44
CO ppm	1.8	4.7	2.9	0.7	0.6	40	0.973	-0.585	1.2	4.0	2.3

TABLE 24. TEST 2-5 CONTINUOUS EMISSION MONITOR RESULTS SUMMARY

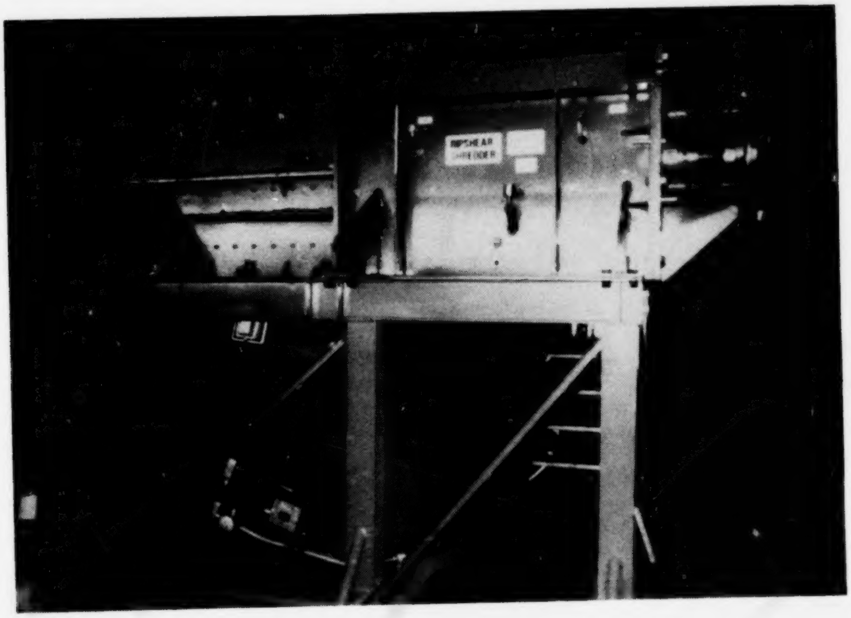
Parameter	Raw Data Test Minimum	Test Maximum	Test Average	Test Std. Dev.	Test Variance	No. Data Points	Calibration Coefficients Slope	Intercept	Corrected Data Test Minimum	Test Maximum	Test Average
Stream 1/ O2 %	7.77	8.51	8.06	0.2	0.1	8	1.051	-0.687	7.48	8.26	7.78
CO2 %	10.5	11.1	10.8	0.2	.0	8	1.030	-0.050	10.8	11.4	11.1
CO ppm	3.6	4.2	3.8	0.2	.0	8	0.942	0.215	3.6	4.2	3.8
THC ppm	0.0	0.0	0.0	0.0	0.0	8	0.808	0.927	0.9	0.9	0.9
NOx ppm	151	163	155	4.3	18.2	8	1.059	2.460	162	175	166
Stream 2/ O2 %	10.2	13.8	11.6	0.5	0.3	126	0.994	-0.147	10.0	13.6	11.4
CO2 %	6.17	9.07	7.94	0.4	0.2	126	1.022	-0.053	6.25	9.22	8.06
CO ppm	0.0	3.3	2.9	0.4	0.2	126	0.863	-0.121	0.0	2.7	2.3
THC ppm	0.0	0.6	0.2	0.2	.0	126	0.773	0.919	0.9	1.4	1.1
NOx ppm	64	113	82	9.7	93.3	125	1.176	1.386	77	134	97
Stream 3/ O2 %	4.24	8.53	6.25	0.7	0.5	116	1.059	-0.201	4.29	8.83	6.42
CO ppm	0.0	16.5	3.5	2.2	5.1	116	1.047	-1.134	0.0	16.1	2.5

APPENDIX B

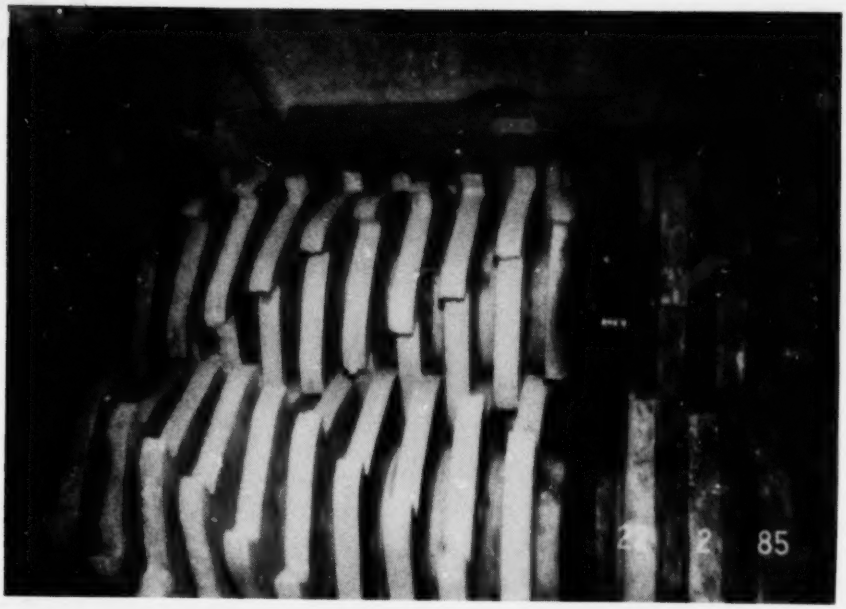
PHOTOGRAPHS



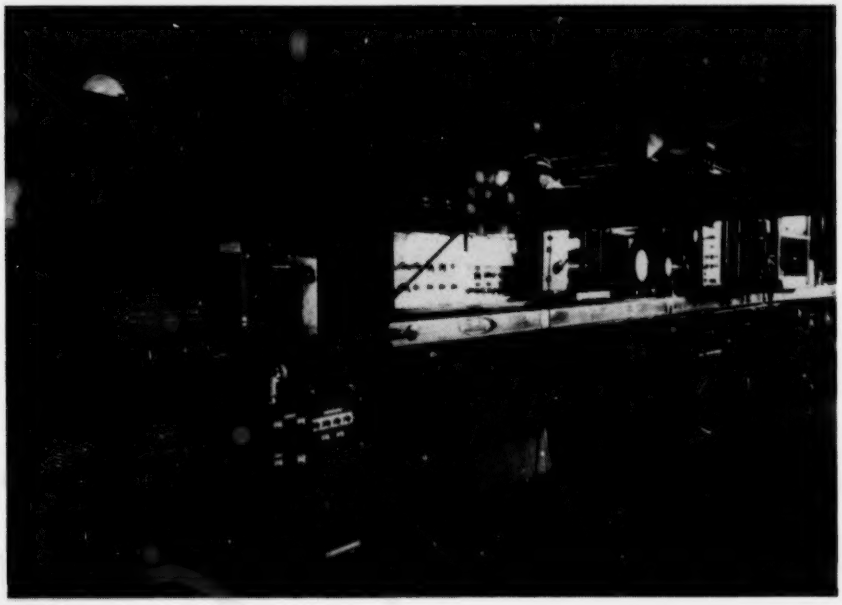
MOBILE INCINERATION SYSTEM AT EDISON, NJ, FALL, 1982
DURING LIQUID TRIAL BURNS


RIPSHEAR
SHREDDER

SHREDDER SYSTEM - PART OF SOLIDS FEED MODIFICATIONS TO MIS



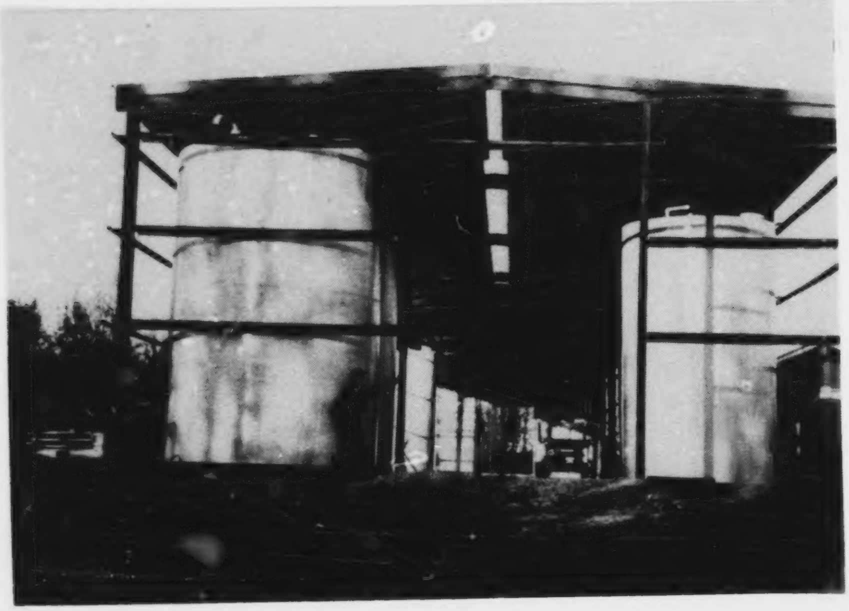
TEETH OF SHREDDER - THIS SYSTEM CAN SHRED A 55 GALLON DRUM OF SOLIDS IN AN OVERPACK, RAILROAD TIES, DRY SOILS, AND ALMOST ANYTHING ELSE



CONTROL PANELS OF MOBILE INCINERATION SYSTEM, SET UP AT EDISON, NJ, DURING HOT TESTS, NOVEMBER, 1984

VIEW INTO KILN OF INCINERATION SYSTEM. FLIGHTS HELP CONTROL FLOW OF SOLIDS FROM FEED END TOWARD VIEWER.

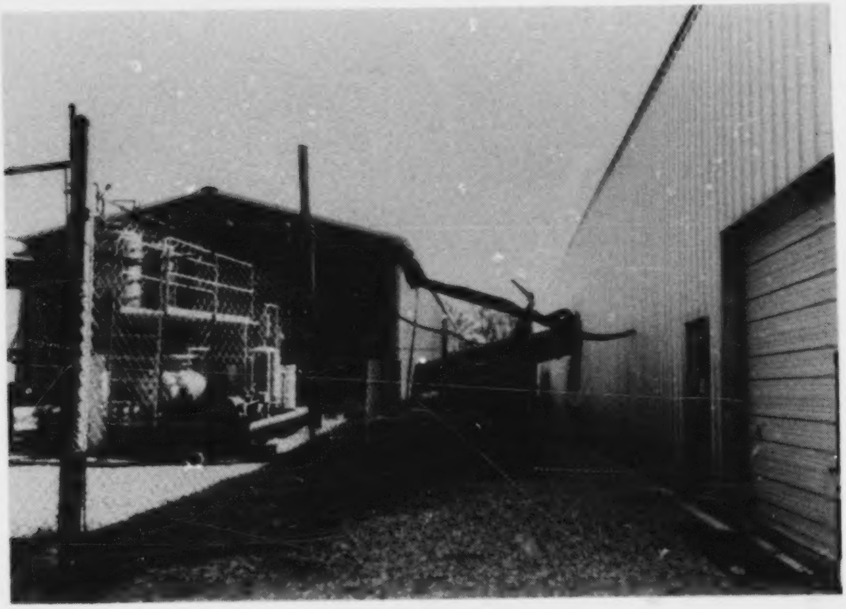
DENNEY FARM SITE BUILDINGS PREVIOUSLY ERECTED BY SYNTEX AS PART OF A PARTIAL SITE CLEANUP. BUILDINGS ON LEFT HOUSE LOOSE SOILS AND DRUMMED WASTES.



NEW BUILDING BEING ERECTED AT DENNEY FARM SITE TO HOUSE MOBILE INCINERATION SYSTEM, DECEMBER, 1984

SECONDARY COMBUSTION CHAMBER BEING MOVED ONTO DENNEY FARM SITE, DECEMBER, 1984

MOBILE INCINERATION SYSTEM BEING INSTALLED IN NEW BUILDING. NO WALLS YET, RAINWATER COVERS FLOOR.



"DRUM STORAGE BUILDING" ON LEFT HOUSES SHREDDER AND LIQUID FEED EQUIPMENT. THIS BUILDING REQUIRES SPECIAL VENTILIATION CONTROLS AND PERSONNEL PROTECTION. INCINERATOR BUILDING ON RIGHT IS CONNECTED TO THE FEED SYSTEM VIA AN ENCLOSED AND VENTILATED CONVEYOR AND LIQUID FEED LINES. NO SPECIAL PERSONNEL PROTECTION IS REQUIRED IN THE INCINERATOR BUILDING.

VIEW OF INCINERATOR BUILDING AT DENNEY FARM, DIOXIN TRIAL BURN, APRIL, 1985

APPENDIX C

ANNOTATED INDEX

APPENDIX C

ANNOTATED INDEX

Consolidated Trial Burn Plan, Quality Assurance Project Plan, and Detailed Sampling/Analytical Procedures, December 6, 1984

Contains the detailed QA/QC Plan and S&A Plan for the Trial Burn and Field Demonstration of the USEPA Mobile Incineration System at the James Denney Farm site in McDowell, Missouri. The contents includes:

Section I - Project Description

Section II - Detailed Engineering Description

Section III - Trial Burn Procedures

Delisting of Ash, Filter Media and Other Solids from the USEPA Mobile Incineration System Field Demonstration at Denney Farm, July 25, 1985

The document contains the formal granting of delisting by EPA's Office of Solid Wastes for certain solid and liquid by-products generated by the EPA Mobile Incineration System during the Field Demonstration at Denney Farm, as published in the July 25, 1985 Federal Register, Vol. 50, No. 143. The document also contains MDNR's formal granting of delisting for these same by-products.

Delisting Petition for Wastewater, Ash, Filter Media and Other Solids from the USEPA Mobile Incineration System Field Demonstration at Denney Farm McDowell, Missouri, April 19, 1985

The petition requests MDNR and EPA's Office of Solid Waste to delist from the RCRA regulations certain solid and liquid by-products generated by the EPA Mobile Incineration System during the Field Demonstration at Denney Farm. The document lists the types of materials to be delisted as well as proposed delisting parameters. The document also includes a supplement to the original petition, dated May 14, 1985.

EERU Mobile Incineration System Capital Cost Estimate Project, April 19, 1983

This report details the costs involved in reproducing the EPA Mobile Incineration System. Maximum, minimum and probable cost estimates are provided. Cost estimates are also given for each of the major pieces of equipment.

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Engineering Package for the USEPA Mobile Incineration System, 4 Volumes

Volumes 1 & 2 of this document contain the 36 MB Associates Progress Reports on the construction and fabrication of the USEPA Mobile Incineration System. Volume 3 contains a draft of the Incineration System Operating Manual, the Stack Monitoring System Operating Manual and the Safety Operating Manual. Volume 4 contains a capital cost estimate for the Mobile Incineration System, an engineering description of the Mobile Incineration System, and Equipment List, a Pipe Line List, an Instrument List, Piping Specifications Sheets and Equipment Specification Sheets for the systems. There are approximately 150 drawings that describe the Mobile Incineration System.

Evaluation of Incineration for On-Site Treatment of Hazardous and Toxic Substances and Dioxin-Contaminated Materials (The Missouri Project), Revised General Work Plan, December 3, 1985

Contains the revised work plan for the Field Demonstration at Denney Farm. Sections include:

A. Field Demonstration Activities
B. Revision of Permits
C. Personnel Safety and Training
D. Decontamination and Demobilization
E. Overall Administration/Management
F. Overall Costs and Schedules

Final Permit Application, USEPA Mobile Incineration System at the James Denney Farm Site, McDowell, Missouri, December 14, 1984, Volumes I and II

Contains the final RCRA permit application for the Trial Burn and Field Demonstration of the EPA Mobile Incineration System at Denney Farm. This document also served to meet the requirements of the Missouri Department of Natural Resources Hazardous Waste Regulations and the Missouri Department of Natural Resources Air Pollution Control Regulations. The document contains the following sections:

Section A - USEPA and State of Missouri Application Forms

Section B - Facility Description

Section C - Waste Characteristics

Section D - Process Information

Section E - Ground Water Monitoring

Section F - Procedures to Present Hazards

Section G - Contingency Plan

Section H - Personnel Training

Section I - Closure

Health Profile for Denney Farm, Missouri, Dioxin Site, EPA Tag No. DW 89930901 (P15992), November, 1984

Contains a health profile and risk assessment performed by Battelle Seattle Research Center of the communities surrounding the Denney Farm site as regards the operation of the Mobile Incineration System in McDowell, Missouri. The report includes the following sections:

Introduction

Statistical Considerations

Approach

Summary of Findings

Laboratory Investigation of Thermal Treatment of Soil Contamination with 2, 3, 7, 8 - TCDD, July, 1984

This document discusses the laboratory study performed on dioxin contaminated soil. The study was initiated to support the preparation of the EPA Mobile Incineration System for the Trial Burn and Field Demonstration at the Denney Farm in McDowell, Missouri.

The contents of the report include:

1. Introduction
2. Conclusions and Recommendations
3. Soil Characteristics and Selection
4. Experimental and Analytical Procedures
5. Results and Discussions

Appendices

A. Summary of Theory and Technical Development

B. Information on Missouri Dioxin Sites

C. EPA Analytical Data for Denney Farm Soil Samples

D. Soil Properties and Test Methods (Battelle Report)

E. Minerological Information for Candidate Test Soils

F. QA/QC Results

G. Analytical Methods

H. Analytical Data

I. Experimental Data

J. Statistical Methodology and Results

Missouri Department of Natural Resources Air Pollution Permit, October 24, 1984

Allows construction and testing of the EPA Mobile Incineration System at Denney Farm. The document lists compliance conditions and notification procedures.

Missouri Department of Natural Resources Air Pollution Permit Application

(See Final Permit Application, USEPA Mobile Incineration System at the James Denney Farm Site, McDowell, Missouri, December 14, 1984).

Missouri Department of Natural Resources Hazardous Waste Incinerator and Storage Permit, October 19, 1984, and subsequent amendments, various dates

Contains responses to public hearing held on September 20, 1984. Also contains the following sections:

Section I - Storage in Tanks

Section II - Incineration

Section III - Short Term Incineration

Section IV - Health Profile

Missouri Department of Natural Resources Hazardous Waste Permit Application

(See Final Permit Application, USEPA Mobile Incineration System at the James Denney Farm Site, McDowell, Missouri, December 14, 1984).

Mobile Incineration System Trial Burn Quality Assurance Project Plan (for Edison, NJ), December 30, 1982

This document addresses the quality assurance and quality control procedures used during the trial burns conducted at the EPA's GSA Raritan Depot facility in Edison, NJ. The document contains:

1. Project Description
2. Project Organization and Responsibilities
3. Quality Assurance Objectives
4. Sampling and Data Collection Procedures
5. Sample Custody
6. Calibration Procedures and Frequency

7. Analytical Procedures
8. Data Analysis, Validation, and Reporting
9. Internal Quality Control Checks
10. System and Performance Audits
11. Preventive Maintenance
12. Specific Procedures to be Used Routinely to Assess Data Precision
13. Accuracy and Completeness
14. Corrective Action
15. Quality Assurance Reports to Management
16. Trial Burn Plan for the U.S. Environmental Protection Agency Mobile Incineration System at EPA Region II Facility, Edison, NJ, Revised February 26, 1982, Supplement 2.

National Environmental Policy Act (NEPA) Application for USEPA Mobile Incineration System, August 16, 1984

Contains the Environmental Assessment Summary and proposed Finding Of No Significant Impact for USEPA Mobile Incineration System when used at uncontrolled hazardous waste sites.

National Environmental Policy Act "Permit," September 24, 1984

Finding of No Significant Impact for the USEPA Mobile Incineration System at Uncontrolled Hazardous Waste Sites published by the EPA Office of Research and Development in the September 24, 1984 Federal Register, Vol. 49, No. 186

Operating and Maintenance Manual for EPA Mobile Incineration System, January 8, 1985

This document is the overall operating manual for the Mobile Incineration System. It contains the following sections:

1. Introduction

2. Preparation for Transport

3. System Setup On-Site

4. Calibration Procedures

5. Incinerator Startup Procedures

6. Control Systems

7. Interlock Control and Alarms

8. Routine Operating Procedures

9. Troubleshooting

10. Normal Shutdown Procedures

Permit Compliance Summary for EPA Mobile Incineration System at Denney Farm, October, 1986

This document summarizes all of the regulatory requirements for site personnel to insure that these requirements are adhered to.

Personnel Training Documents for the USEPA Mobile Incineration System at the Denney Farm Site, January, 1985

The document contains the entire health, safety and training program used to train personnel who would be working at the Denney Farm site.

The document contains the following sections:

I. Health and Safety Manual

II. General Safe Work Practices

III. Safe Work Practice Theory

IV. Personnel Protective Equipment

V. Respiratory Protection Equipment

VI. Safety Meetings, Inspections, and Recordkeeping

VII. Lockout of Power Driven Equipment

VIII. Cylinder Handling, Drum Handling, and Safe Lifting

IX. Gauges, Sight Glasses and Inclined Manometers

X. Toxic Hazards

XI. Site Specific Toxic Hazards

XII. Sampling Protocols

XIII. Emergency Equipment Use and Procedures

XIV. Decontamination Procedures

XV. Spill Prevention, Cleanup and Waste Disposal

XVI. Flammable Hazards

XVII. Fire Protection Theory

XVIII. Fire Protection Exercise

XIX. Additional Required Safety Plans

XX. Appendices

Preliminary Feasibility Study - Transportable Incineration Systems, 2 Volumes, May, 1984

This document reviews the technical financial and institutional viability of transportable incineration systems. The document contains the following sections:

1. Introduction
2. Summary
3. Identification of Superfund Sites Containing Incinerable Wastes
4. Evaluation of Capabilities of Existing Transportable Incineration Systems
5. Evaluation of Potential Use of Existing Cement, Lime, and Aggregate Kilns for Hazardous Waste Incineration
6. Location Survey of Commercial Incineration Facilities
7. Effects of Institutional Requirements
8. Evaluation of Transportation Options for a Transportable Incinerator
9. Transportable Incinerator Conceptual Process Design
10. Economic Analysis
11. Missouri Dioxin Contaminated Site Cleanup Case Study
12. New Jersey NPL Site Cleanup Case Study

Appendices

A. Example Site Inspection and Hazard Ranking Forms

B. Superfund Sites on National Priorities List with Incinerable Waste

C. Compliance with Other Environmental Acts Draft Policy on CERCLA

D. Literature Citations - Movable Incineration System

E. Literature Citations - Incineration of Hazardous Waste in Cement, Lime, and Aggregate Kilns

F. Heat and Material Balance, Case I

G. Heat and Material Balance, Case II

Resource Conservation and Recovery Act (RCRA) Permit Application

(See Final Permit Application, USEPA Mobile Incineration System at the James Denney Farm Site, McDowell, Missouri, December 14, 1984).

Resource Conservation and Recovery Act (RCRA) Permit for the Operation of the USEPA Mobile Incineration System at Denney Farm, McDowell, Missouri, October 14, 1984 and subsequent amendments, various dates

Contains the permit and subsequent amendments to the permit to operate the Mobile Incineration System at Denney Farm. Also contains a responsive summary for the public hearing held on behalf of the permit application in Cassville, Missouri on September 20, 1984. The document includes:

Section I. - Standard Conditions

Section II. - General Facility Conditions

Section III. - Storage In Tanks

Section IV. - Incineration

Section V. - Short Term Incineration Permit

Toxic Substances Control Act Permit Application for the USEPA Mobile Incineration System, August 3, 1984

The application is on behalf of a request to the EPA Office of Toxic Substances to approve the incineration of PCBs during the Trial Burn and Field Demonstration of the EPA Mobile Incineration System at Denney Farm.

The contents include:

Section 1 - Introduction

Section 2 - Application Forms

Section 3 - Schedule

Section 4 - Data Reporting

Section 5 - SPCC Plan

Section 6 - Region II TSCA Permit

Section 7 - Region II RCRA Permits

Section 8 - Region VII and MDNR Permit Application

Section 9 - Safety Manual

Trial Burn Plan for the U.S. Environmental Protection Agency Mobile Incineration System at EPA Region II Facility, Edison, NJ, Revised February 26, 1982, Supplement 2 (see Mobile Incineration System Trial Burn Quality Assurance Project Plan)

USEPA Mobile Incineration System Particulate Drop-Out Feasibility Study, March 22, 1985

This report discusses the engineering and economic viability of adding a dropout box to the front of the Mobile Incinerator's Secondary Combustion Chamber. The contents of the report includes:

I. - Introduction

II. - Priority Process Areas Requiring Attention

III. - Summary

IV. - Technical Discussion Summary

Appendix A - Rotary Kiln and Secondary Combustion Chamber

Appendix B - Flue Gas Cleaning and Air Balance Control

Appendix C - Cost and Schedule Estimates

USEPA Mobile Incineration System Phase I Trial Burn Results, GSA Raritan Depot, October 15, 1982, 3 Volumes

This 3 volume document contains detailed information on the shakedown and testing of the Mobile Incineration System in Edison, NJ. Phase I of the Trial Burn consisted of 4 sampling and analytical runs designed to provide baseline data on the incineration system.

USEPA Mobile Incineration System Phase II Interim Trial Burn Results, GSA Raritan Depot, December 10, 1982, 12 Volumes

This 12 volume document contains detailed information on the second phase of the trial burn. Phase II consisted of tests designed to measure the particulate matter removal efficiency of the air pollution control system the HCL removal efficiency of the air pollution control system, and the destruction and removal efficiency of carbon tetrachloride and ortho-dichlorobenzene, both RCRA regulated organics.

USEPA Mobile Incineration System Phase III Trial Burn Data Package, GSA Raritan Depot, April 19, 1983, 7 Volumes

This 7 volume document contains detailed information on the third phase of the trial burn. Phase III consisted of two tests where the destruction and removal efficiency of two different concentrations of "Askarel," a PCB/trichlorobezene mixture, were measured along with the particulate matter and HCl removal efficiencies of the air pollution control system.

LIST OF ENGINEERING, DESIGN, AND INSTRUMENTATION DOCUMENTS

I. SYSTEM DRAWINGS - 31 sheets -24"x36"

A. Piping and Instrumentation Diagrams (11 sheets of 31)

This group of drawings show the detailed piping and instrumentation of the Mobile Incineration System. Two drawings present the symbols, with notes, used to depict the control valves and control instruments. Two drawings represent the symbols and notes used to depict piping and equipment. The remaining seven drawings show all flows through and operating controls beginning with the hydraulic systems driving the solid feeder and the kiln, moving in order through the unit, and ending with the support systems.

9822-000-601	Rev 1	IT[a]	CONTROL SYSTEM STANDARDS
9822-000-602	Rev 1	IT	CONTROL SYSTEM STANDARDS
9822-000-603	Rev 1	IT	PIPING & EQUIPMENT IDENTIFICATION
9822-000-604	Rev 1	IT	PIPING & EQUIPMENT IDENTIFICATION
9822-100-131	Rev 2	IT	RAM FEED/HYDRAULIC UNIT
9822-100-132	Rev 2	IT	ROTARY KILN-TRAILER NO.1
9822-200-131	Rev 2	IT	SECONDARY COMBUSTION CHAMBER-TRAILER NO. 2
9822-300-131	Rev 2	IT	AIR POLLUTION CONTROL-TRAILER NO.3
9822-300-132	Rev 2	IT	INSTRUMENT AIR SYSTEM
9822-400-130	Rev 2	IT	DIESEL FUEL & WASTE OIL DISTRIBUTION SYSTEMS
9822-400-131	Rev 2	IT	CAUSTIC, STEAM & WASTEWATER SYSTEMS

B. Plans and Sections (10 sheets of 31)

These drawings consist of plans, elevations, and sections which show the detailed arrangements of equipment and piping. The drawings are to scale.

9822-000-001	Rev 1	IT	FIELD LAYOUT Plot Plan
9822-100-501	Rev 1	IT	TRAILER NO. 1 PIPING LAYOUT Plan and Elevation
9822-100-502	Rev 1	IT	TRAILER NO. 1 PIPING SECTIONS
9822-200-501	Rev 1	IT	TRAILER NO. 2 PIPING LAYOUT Plan and Elevation
9822-200-502	Rev 1	IT	TRAILER NO. 2 PIPING LAYOUT Detailed sections
9822-300-501	Rev 1	IT	TRAILER NO. 3 PIPING LAYOUT Plan and elevation

9822-300-502	Rev. 1	IT	PIPING SECTIONS
9822-400-501	Rev. 1	IT	WASTE LIQUID FEED/MIX AREA PIPING LAYOUT Plan and elevation
9822-400-502	Rev. 1	IT	CAUSTIC/WASTE WATER PIPING LAYOUT Plan, elevations, and sections
9822-400-503	Rev. 1	IT	AUXILIARY AIR DRYER PIPING LAYOUT Plan and elevation

C. Instruments and Controls (10 sheets of 31)

These drawings show the detailed electrical control circuits for the operating systems in schematic (Ladder Diagram) form.

9822-000-702	Rev. 5	IT	ELECTRICAL CONTROL DRAWING Pump Controls
9822-000-703	Rev. 4	IT	ELECTRICAL CONTROL DRAWING Cheaf and Quencher
9822-000-704	Rev. 3	IT	ELECTRICAL CONTROL DRAWING Control plus Control Logic-Solid Feed System
9822-000-705	Rev. 5	IT	ELECTRICAL CONTROL DRAWING Misc. Controls, Monitors, Shut-down circuits
9822-000-706	Rev. 5	IT	ELECTRICAL CONTROL DRAWING Kiln Controls
9822-000-707	Rev. 5	IT	ELECTRICAL CONTROL DRAWING Emergency Controls
9822-000-708	Rev. 5	IT	ELECTRICAL CONTROL DRAWING Misc. Valves,Pump, Indicators
9822-000-709	Rev. 5	IT	TRAILER NO.1 BURNER CONTROLS Kiln Burner Controls
9822-000-710	Rev. 5	IT	TRAILER NO. 2 BURNER CONTROLS SCC Burner Controls
9822-400-701	Rev. 5	IT	BOILER CONTROLS AND ELECTRICAL CONTROL CIRCUITS Boiler, ID Fan Diesel, Alarm Lights & Horn

II. DRAWINGS FROM EQUIPMENT MANUFACTURER - 135 Sheets -Miscellaneous Sizes.
Note: Most of these drawings are marked proprietory

These are manufacturer's drawings which show the detailed design, fabrication and installation procedures for their equipement supplied for the Mobile Incineration System. These are identified by the number supplied by the manufacturer. In some instances, drawings were assigned new numbers. In these cases the former numbers are shown in parentheses.

A. Equipment Details Kiln (84 sheets of 135)

Drawings of equipment items include detailed plan and elevation drawings (in some instances, orthographic projections) including section details and installation instructions.

33801	Rev. 1	Anderson 2000[b]	FLAT BED CHEAF UNIT ASSEMBLY DRAWING
33803	Rev. 2	Anderson 2000	FLAT BED CHEAF UNIT FRAME WELDMENT
33804	Rev. 1	Anderson 2000	FLAT BED CHEAF UNIT INLET PLENUM DETAILS
33805	Rev. 1	Anderson 2000	FLAT BED CHEAF UNIT SUCTION PLENUM
33806	Rev. 1	Anderson 2000	FLAT BED CHEAF UNIT HOLD DOWN BAR ASSEMBLY
33807	Rev. 0	Anderson 2000	FLAT BED CHEAF UNIT ACCESS DOORS
33808	Rev. 0	Anderson 2000	FLAT BED CHEAF UNIT STAPLE PLATE, MANDRELS & GUIDES
33809	Rev. 0	Anderson 2000	FLAT BED CHEAF UNIT CHAIN GUARD & INLET PLENUM GASKET
33810	Rev. 0	Anderson 2000	FLAT BED CHEAF UNIT WIRE BELT GUIDE ROLLER, ROLLER MOUNTING PLATE
33811	Rev. 1	Anderson 2000	FLAT BED CHEAF UNIT INLET BOX DETAIL
33812	Rev. 0	Anderson 2000	FLAT BED CHEAF UNIT PIN DRIVE ____ PART 110 40
33813	Rev. 0	Anderson 2000	FLAT BED CHEAF UNIT LIMIT SWITCH DETAIL, SPRAY NOZZLE ASSEMBLY
33814	Rev. 1	Anderson 2000	FLAT BED CHEAF UNIT OVERALL DIMENSIONS
D2-3926	Rev. E	Buffalo Forge[c]	55-4 R' FAN ASSY. APR 1 DETAILS OF ID FAN
115429		MBA[d]	AFTERBURNER FLOW NOZZLE ASSEMBLY SCC DETAIL
115439		MBA	AFTERBURNER ENTRANCE
115445	Rev. C	MBA	QUNCH ELBOW AFTERBURNER Detail Quench Elbow and Spray
115510	Rev. C	MBA	FLUE GAS COLLECTOR TUBES
115553	Rev. C	MBA	AFTERBURNER ASSEMBLY
115560	MBA		AFTERBURNER INLET
115598	Rev. A	MBA	DETOX ROTARY KILN ASSEMBLY 2 Sheets
115599	Rev. A	MBA	BURNER END DETAIL Detail of Kiln inlet end
115600	Rev A	MBA	ASH END DETAIL 2 Sheets
115601	Rev. B	MBA	KILN CYLINDER ASSEMBLY 2 Sheets
115602	Rev. A	MBA	KILN CYLINDER BURNER END DETAIL
115603	Rev. A	MBA	KILN CYLINDER- ASH END DETAIL
115604	Rev. A	MBA	KILN CYLINDER - CENTER SECTION DETAIL
115605	Rev. A	MBA	KILN RAIL DETAIL
115606-115608		MBA	KINL MISCELLANEOUS DETAILS
115609	Rev. A	MBA	THERMOCOUPLE WELL & HELICAL FLIGHT PADDLE
115610	Rev. A	MBA	TRAILER INSTALLATION Kiln Mounting Details
115630		MBA	AFTERBURNER BODY-BODY ASSEMBLY

			SCC Body Details
115640		MBA	AFTERBURNER SHROUD
115667		MBA	ASSY TRAILER NO. 2 SCC Trailer details
115782		MBA	BREECH SECTION
115783		MBA	BREECH DUCT DETAILS 8 Sheets (9 of 9 missing)
115784	Rev. 0	MBA	QUENCH SUMP INLET DUCT 3 Sheets
115785	Rev. 0	MBA	QUENCH SUMP 2 Sheets
115786	Rev. 0	MBA	QUENCH SUMP DISCHARGE DUCT
115787		MBA	SAFETY ELBOW 2 Sheets
115789		MBA	ASH CHUTE DETAILS 5 Sheets
115798		MBA	RAM FEEDER DETAILS 8 Sheets
115813		MBA	KILN BURNER MOUNT DETAILS & ASSEMBLY 2 Sheets
115814		MBA	AFTERBURNER MOUNTING DETAILS SCC Burner Installation
115815		MBA	AFTERBURNER BOOM
SK115830		MBA	REFLOW BLEED CONTROL VALVE
SK115876		MBA/Peerless[e]	TRAILER NO. 1 DETAILS 4 Sheets
SK115899		MBA/Peerless	TRAILER NO. 2 DETAILS
SK115900		MBA/Peerless	TRAILER NO. 3 DETAILS
115822		MBA/Cielcote[f]	MX SCRUBBER DETAILS 3 Sheets
115853		MBA/Cielcote	REFLOW PIPING

B. Monitoring Instruments (16 Sheets of 135)

This group of drawings shows the details of sampling probes, analyzed electrical diagrams and installation details. Most are standard drawings of "off the shelf" items.

B7731-F (3521949-5 Rev.A)	Bendix[g]	OUTLINE & MOUNTING STANDARD CALIBRATION ASSEMBLY MODEL 8905
B7731-Z (3521376-26 Rev. A)	Bendix	FLOW DIAGRAM 8 SBF-DC-10-SBF-SEL
B7731-A (3521631 Rev. B)	Bendix	OUTLINE AND MOUNTING DIMS. OOZANALYZER Mounting details & tubing connections
B7732-A (3526122 Rev. A)	Bendix	OUTLINE AND MOUNTING DIMS. STEAM EDUCTOR ASSY.
B7732-B (3526081)	Bendix	FLOW DIAGRAM STEAM MODIFICATION Detail control steam flow to probe conditioning assy.

B7733-B (3526252 Rev. A)	Bendix	OUTLINE AND MTG. DIM. CERAMIC PROBE CONDITIONING ASSEMBLY
B7733-C (3521455-2 Rev. A)	Bendix	FLOW DIAGRAM SUPPORT ASSY. Control of zero gas, span gas, plant air, inst. air.
B7733-E&F (3526625-2 Rev. A)	Bendix	INSTALLATION DETAILS FOR STEAM, CERAMIC PROBE COND. BOX, AND SUPPORT ASSEMBLY Wiring diagram with instrument terminals "E" has enclosure cooler on 8901C
B7733-H (3521669-2 Rev. A)	Bendix	INTERCONNECTING DIAGRAM CERAMIC PROBE CONDITIONING/SUPPORT ASSY. TYP. BOTH STREAMS, Detail- Instrument Electrical Connections
B7733-Q (3526252-Rev. A)	Bendix	OUTLINE AND MOUNTING DIM. CERAMIC PROBE CONDITIONING ASSEMBLY
B7734-A (3525062X Rev. D)	Bendix	REAR PANEL TERMINAL IDENTIFICATION 9000 CONTROL Terminals on panel back- numbers and functions
B7735-A (3521631 Rev. B)	Bendix	OUTLINE AND MOUNTING DIMENSIONS 00$_2$ ANALYZER
B7735-Y (3525097-4 Rev. C)	Bendix	FLOW DIAGRAM 002 FID DUAL CARRIER Gas flow to CO, O_2, SO_2, CO_2 Monitors
B7735-Z (3521376-7 Rev. A)	Bendix	FLOW DIAGRAM 10SBF-10SBF Controls for flue gas and carrier
B7736-A Not available	Bendix	OUTLINE AND MOUNTING DIMENSIONS MOBILE STACK MONITORING SYSTEM
B7736-C Not available	Bendix	STACK SAMPLE SYSTEM DUAL STREAM

C. Conditioning Panel Assembly (5 sheets of 135)

These drawings provide the details, including the internals, of the flue gas conditioning panel assembly.

3526250 Rev.A	Bendix	PLATE, FLANGE SUPPORT
3526253 Rev.A	Bendix	PANEL, PROBE CONDITIONING MTG. 2 SHEETS
3526256-1 Rev.A	Bendix	ENCLOSURE, FIBERGLASS MODIFIED
3526256-2 Rev.A	Bendix	ENCLOSURE, FIBERGLASS MODIFIED

D. Belt Conveyor Details (17 sheets of 135)

These drawing show details of the belt conveyor, weigh hopper and slide gate systems used for weighing and transporting solid waste to the ram feeder. The drawings include details of equipment, controls, wiring and installation.

5331-1 Rev.1	Lecorp[h]	PORTABLE FLEXIBLE WALL BELT CONVEYOR Elevation drawing
5331-2 Rev.3	Lecorp	ASSEMBLY - CONVEYOR UNIT
5331-3 Rev.3	Lecorp	DETAILS - CONVEYOR FRAME
5331-4-		

5331-6	Lecorp	MISCELLANEOUS CONVEYOR DETAILS
5331-7 Rev.1	Lecorp	DETAIL WEIGH HOPPER & SLIDE GATE ASSEMBLY
5331-8 Rev.0	Lecorp	WEIGH HOPPER SUPPORT STRUCTURE
5331-9 Rev.0	Lecorp	ZERO SPEED SWITCH BRACKETS
5331-10 Rev.0	Lecorp	SHREDDER SUPPORTS
5331-11 Rev.0	Lecorp	MISCELLANEOUS DETAILS
5331-12 Rev.0	Lecorp	FLEXIBLE BOOT DETAILS
5331-13 Rev.0	Lecorp	DETAIL- LIMIT SWITCHES AND MOUNTING BAR FOR SLIDE GATE
5331-14 Rev.1	Lecorp	DETAIL-DUST COVER FOR SLIDE GATE
5331-15 Rev.0	Lecorp	DETAIL-SEAL PLATES
E-100 Rev.0	Lecorp	LAYOUT- SYSTEM FIELD WIRING
M-100 Rev.1	Lecorp	ZERO SPEED SWITCH & SEAL PLATE ASSEMBLY

E. Additional Drawings (13 sheets of 135)

The following drawings provide details of additional sampling equipment. More details are not available at this time.

408B10	Imp. Prod.	INCONEL PROBE ASSEMBLY
408A20	Imp. Prod.	EXTENSION TUBE
408A21	Imp. Prod.	COUPLING
408A22	Imp. Prod.	BARREL
408A23	Imp. Prod.	FILTER
408A24	Imp. Prod.	MOUNTING FLANGE
408A25	Imp. Prod.	REDUCER
408A26	Imp. Prod.	SPHERICAL JOINT
408A28	Imp. Prod.	INTERMEDIATE FLANGE
408A29	Imp. Prod.	JET
408A30	Imp. Prod.	EDUCTOR
408A31	Imp. Prod.	EDUCTOR VALVE STEM
408A32	Imp. Prod.	EDUCTOR VALVE STEM ARM

III. ADD ON DRAWINGS - 15 Sheets - 24" x 36"

These drawings provide details of an addition to the Secondary Combustion Chamber. This addition to the unit was made before the test burns in Missouri were begun. The addition was for relocation of the burners and the addition of clean-out facilities.

9725-ADON-1 Rev.2 thru 4 Rev. 1	IT	ADON FOR SECONDARY COMBUSTION CHAMBER Details of design of added section.
9725-ADON-5 Rev.0	IT	BREECH (HOT) DUCT FOR ADON TO SCC- Section drawings for field erection
9725-ADON-6 Rev.0	IT	BREECH DUCT - TUBE A (101)
9725-ADON-7 Rev.0	IT	BREECH DUCT - FLANGE A (102)
9725-ADON-8 Rev.0	IT	BREECH DUCT - GLAND A (103)
9725-ADON-9 Rev.0	IT	BREECH DUCT - FLANGE B (105)
9725-ADON-10 Rev.0	IT	BREECH DUCT - GLAND B (106)

9725-ADON-11	Rev.0	IT	BREECH DUCT - TUBE B (107)
9725-ADON-12	Rev.2	IT	OBSERVATION DOORS FOR ADON FOR SCC
9725-ADON-13	Rev.1	IT	RELOCATION OF SCC BURNERS
9725-ADON-14	Rev.1	IT	AIR PLENUM & STACK FOR SCC SHROUD
9725-ADON-15	Rev.0	IT	TOOLS FOR SCC CLEANOUT

IV. PRINTS - 6 Prints

The following control drawings depict instruments and controls for various systems. They exist as prints only.

9822-100-601	Rev.0	IT	TRAILER #1 TEMP. & AIR FLOW CONTROLS
9822-200-601	Rev.0	IT	TRAILER #2 TEMP. & AIR FLOW CONTROLS
9822-200-701	Rev.1	IT	TRAILER #2 BURNER CONTROL
9827-400-701	Rev.1	IT	ANALYZING TRAILER 9000 CONTROLS
9827-400-702	Rev.0	IT	ANALYZING TRAILER PANEL NO. 3 CONTROLS
9827-400-703	Rev.0	IT	ANALYZING TRAILER STEAM GENERATOR CONTROL WIRING DIAGRAM

V. Suppliers

For further information on equipment shown on drawings, contact the following:

a. IT Corporation
GSA-Raritan Depot
Building 209, Bay F
Edison, NJ 08837

b. Anderson 2000, Inc.
306 Dividend Drive
Peachtree City, GA 30209

c. Buffalo Forge Co.
PR Box 505
Route 202-206
Pluckemin, NJ 07978

d. Traycor-MBA
Bollinger Canyon Road
PO Box 196
San Ramon, CA 94583

e. Peerless
Division of Lear-Siegler, Inc.
Tuolatin, OR 97062

f. Ceilcote Company
142 Sheldon Road
Berea, OH 44017

g. Combustion Engineering
PO Box 831
Lewisburg, WV 24901

h. Lecorp
Box 7508
Paducah, KY 42001-0322

i. Improved Products Co.
14 Gifford Road
Somerset, NJ 08873

APPENDIX D
Operating Data Sheets

KILN BURNER 'B 1' CALIBRATION
Tag # FI-104A

Calibration date: _____________

Calibrated by: _____________

Instrument linearity

Indicated (gal/hr)	Measured (mL/sec)	Converted (gal/hr)
_________	______/______	________
_________	______/______	________
_________	______/______	________
_________	______/______	________
_________	______/______	________
_________	______/______	________
_________	______/______	________
_________	______/______	________

Instructions:

1.) Disconnect outlet of rotameter from burner and connect tubing to allow collection of diesel fuel.
2.) Energize diesel fuel transfer system.
3.) Adjust diesel fuel flowrate to desired rate and collect the the discharged fuel in a 2-liter graduated cylinder. Graduated cylinder must have a tolerance of 10 mL and be graduated "To Contain" a volume of liquid.
4.) Collect a minimum of 1500 mL while measuring time with a stopwatch.
5.) Record the volume of fuel collected and elapsed time.
6.) Adjust the flowrate to a new level and repeat the flow measurement.
7.) Recomended calibration points - 5,10,15,20,25,& 15 gal/hr.
8.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate or replace the rotameter.

SAVE ALL CALIBRATION DATA

Formula:

Measured flow (mL/sec) x 0.951 = flowrate (gal/hr)

Reference:

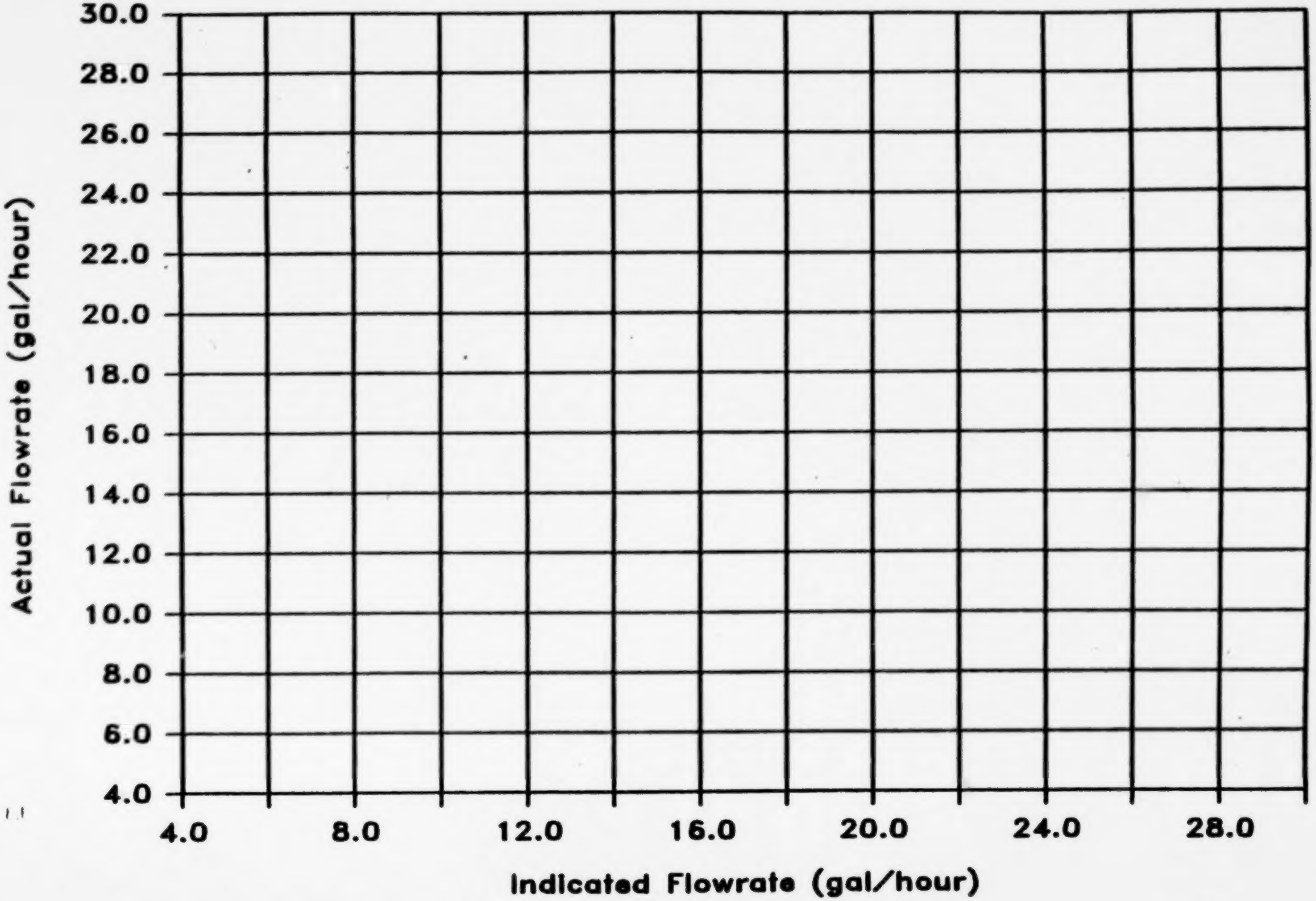
Maxon manual for the flowmeter.

Comments:

____

____

AUXILIARY BURNER FLOWRATE CALIBRATION



KILN BURNER 'B 2' CALIBRATION
Tag # FI-104B

Calibration date: ____________

Calibrated by: ____________

Instrument linearity

Indicated (gal/hr)	Measured (mL/sec)	Converted (gal/hr)
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________

Instructions:

1.) Disconnect outlet of rotameter from burner and connect tubing to allow collection of diesel fuel.
2.) Energize diesel fuel transfer system.
3.) Adjust diesel fuel flowrate to desired rate and collect the the discharged fuel in a 2-liter graduated cylinder. Graduated cylinder must have a tolerance of 10 mL and be graduated "To Contain" a volume of liquid.
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6.) Adjust the flowrate to a new level and repeat the flow measurement.
7.) Recomended calibration points - 5,10,15,20,25,& 15 gal/hr.
8.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate or replace the rotameter.

SAVE ALL CALIBRATION DATA

Formula:

Measured flow (mL/sec) x 0.951 = flowrate (gal/hr)

Reference:

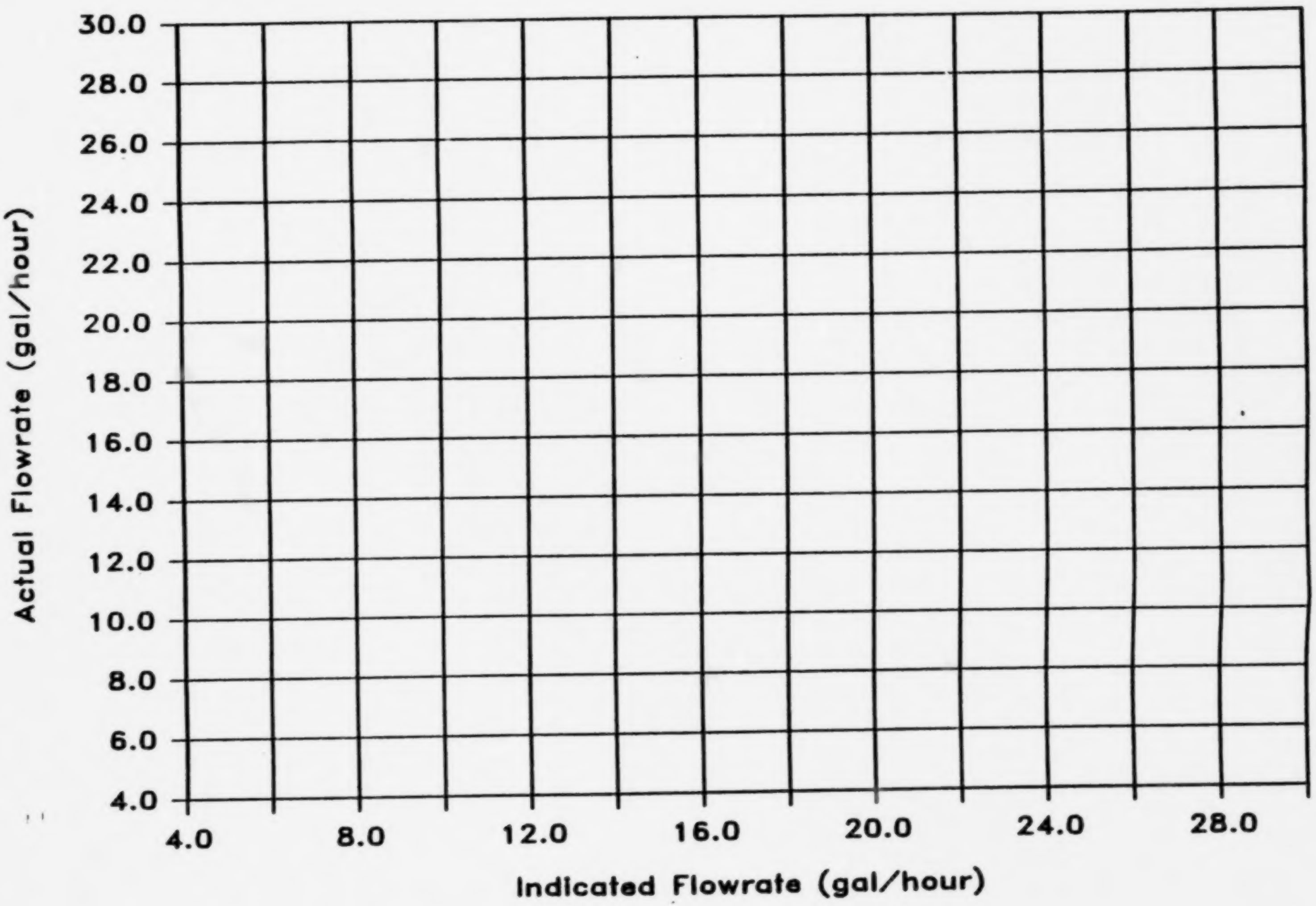
Maxon manual for the flowmeter.

Comments:

____

____

AUXILIARY BURNER FLOWRATE CALIBRATION



SCC BURNER 'B 3' CALIBRATION
Tag # FI-201A

Calibration date: ______________

Calibrated by: ______________

Instrument linearity

Indicated (gal/hr)	Measured (mL/sec)	Converted (gal/hr)
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________
________	______/______	________

Instructions:

1.) Disconnect outlet of rotameter from burner and connect tubing to allow collection of diesel fuel.

2.) Energize diesel fuel transfer system.

3.) Adjust diesel fuel flowrate to desired rate and collect the the discharged fuel in a 2-liter graduated cylinder. Graduated cylinder must have a tolerance of 10 mL and be graduated "To Contain" a volume of liquid.

4.) Collect a minimum of 1500 mL while measuring time with a stopwatch.

5.) Record the volume of fuel collected and elapsed time.

6.) Adjust the flowrate to a new level and repeat the flow measurement.

7.) Recomended calibration points - 5,10,15,20,25,& 15 gal/hr.

8.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate or replace the rotameter.

SAVE ALL CALIBRATION DATA

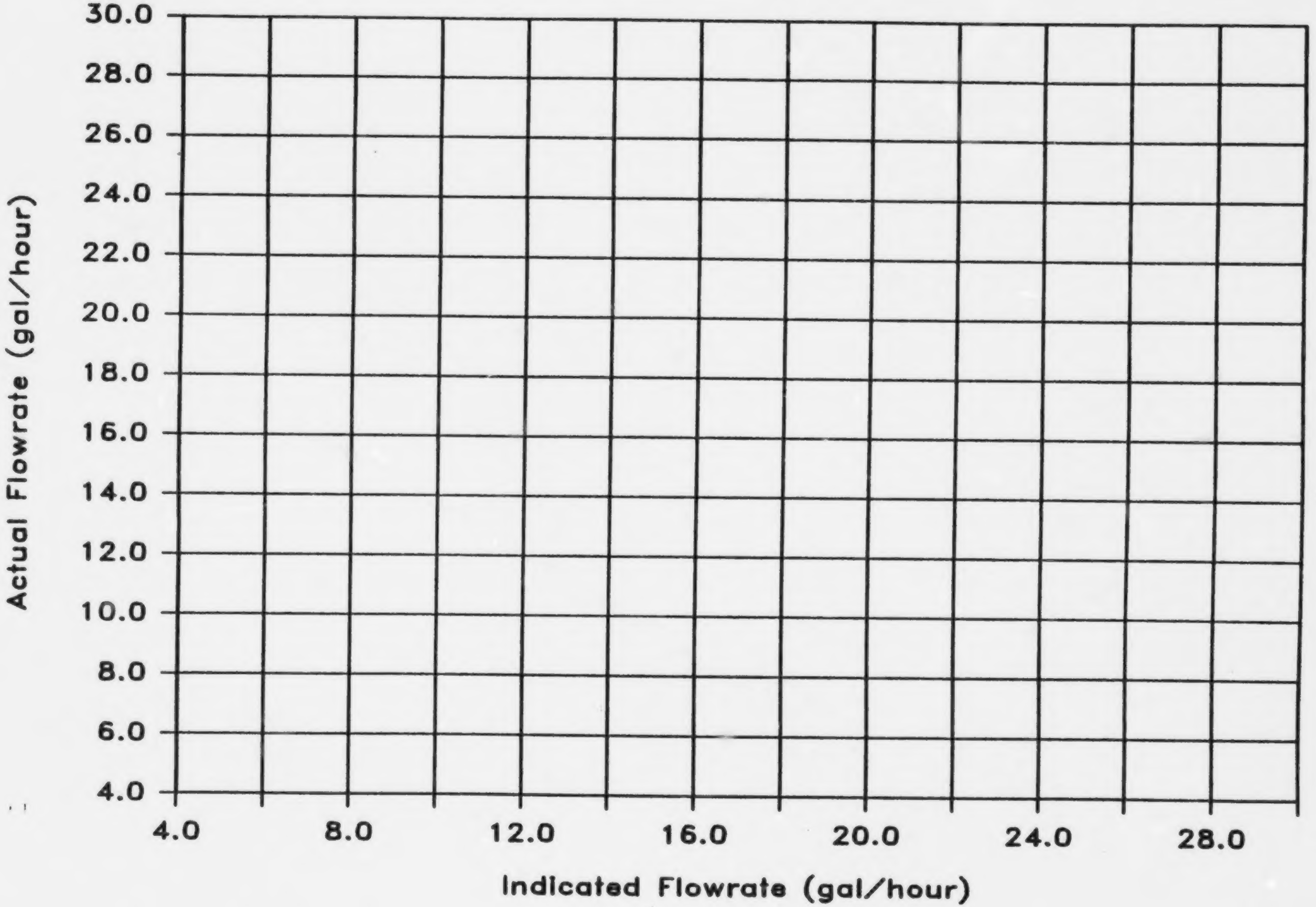
Formula:
Measured flow (mL/sec) x 0.951 = flowrate (gal/hr)

Reference:
Maxon manual for the flowmeter.

Comments: ____

____

AUXILIARY BURNER FLOWRATE CALIBRATION



SCC BURNER 'B 4' CALIBRATION
Tag # FI-204B

Calibration date: _____________

Calibrated by: _____________

Instrument linearity

Indicated (gal/hr)	Measured (mL/sec)	Converted (gal/hr)
---------	------/------	--------
---------	------/------	--------
---------	------/------	--------
---------	------/------	--------
---------	------/------	--------
---------	------/------	--------
---------	------/------	--------
---------	------/------	--------

Instructions:

1.) Disconnect outlet of rotameter from burner and connect tubing to allow collection of diesel fuel.
2.) Energize diesel fuel transfer system.
3.) Adjust diesel fuel flowrate to desired rate and collect the the discharged fuel in a 2-liter graduated cylinder. Graduated cylinder must have a tolerance of 10 mL and be graduated "To Contain" a volume of liquid.
4.) Collect a minimum of 1500 mL while measuring time with a stopwatch.
5.) Record the volume of fuel collected and elapsed time.
6.) Adjust the flowrate to a new level and repeat the flow measurement.
7.) Recomended calibration points - 5,10,15,20,25,& 15 gal/hr.
8.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate or replace the rotameter.

SAVE ALL CALIBRATION DATA

Formula:

Measured flow (mL/sec) x 0.951 = flowrate (gal/hr)

Reference:

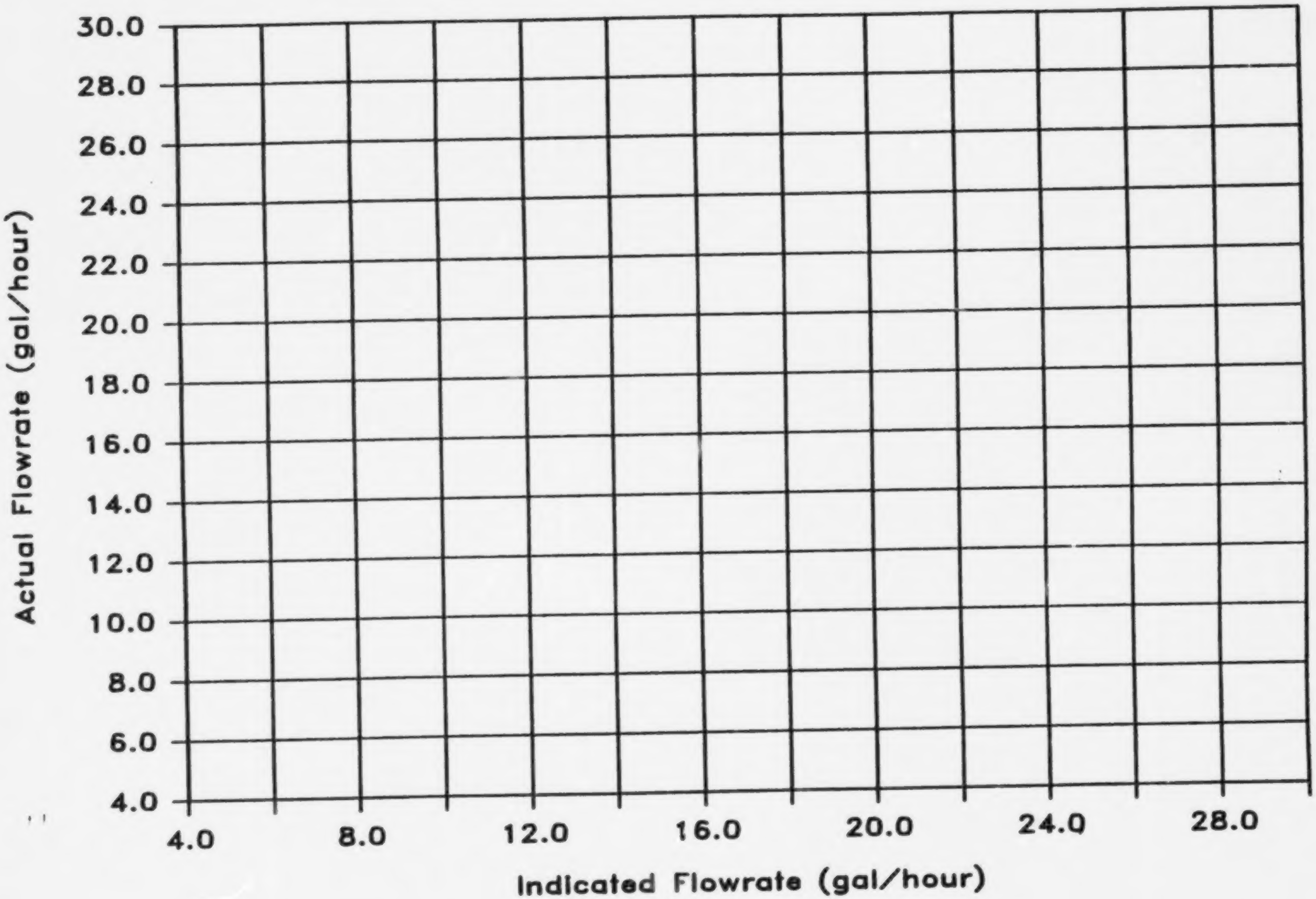
Maxon manual for the flowmeter.

Comments:

____

____

AUXILIARY BURNER FLOWRATE CALIBRATION



WASTE OIL FLOWMETER CALIBRATION
Tag # FI-150

Calibration date: ____________

Calibrated by: ____________

Instrument linearity sp. gr.= ________

Indicated (lb/hr)	Measured (mL/sec)	Converted (lb/hr)
________	________/________	________
________	________/________	________
________	________/________	________
________	________/________	________
________	________/________	________
________	________/________	________
________	________/________	________
________	________/________	________

Instructions:

1.) Insure that waste oil transfer system is not contaminated by examining operating records. If the system has not been decontaminated then follow the procedures in Decontamination Manual before proceeding.
2.) Connect inlet of flowmeter to diesel fuel transfer system.
3.) Disconnect transfer hose on outlet of flowmeter and connect tubing to allow collection of diesel fuel.
4.) Energize diesel fuel transfer system.
5.) Adjust diesel fuel flowrate to desired rate and collect the the discharged fuel in a 2-liter graduated cylinder. Graduated cylinder must have a tolerance of 10 mL and be graduated "To Contain" a volume of liquid.
6.) Collect a minimum of 1500 mL while measuring time with a stopwatch.
7.) Record the volume of fuel collected and elapsed time.
8.) Adjust the flowrate to a new level and repeat the flow measurement.
9.) Recomended calibration points - 50,100,150,200,250,300, 350, & 200 lb/hour.
10.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate flowmeter according to manufacturers instructions or replace the flowmeter. Calibrate new or adjusted flowmeter using new form.

SAVE ALL CALIBRATION DATA

Formula:

Measured flow (mL/sec) x 7.931 x sp.gr. = Actual flow (lb/hr)

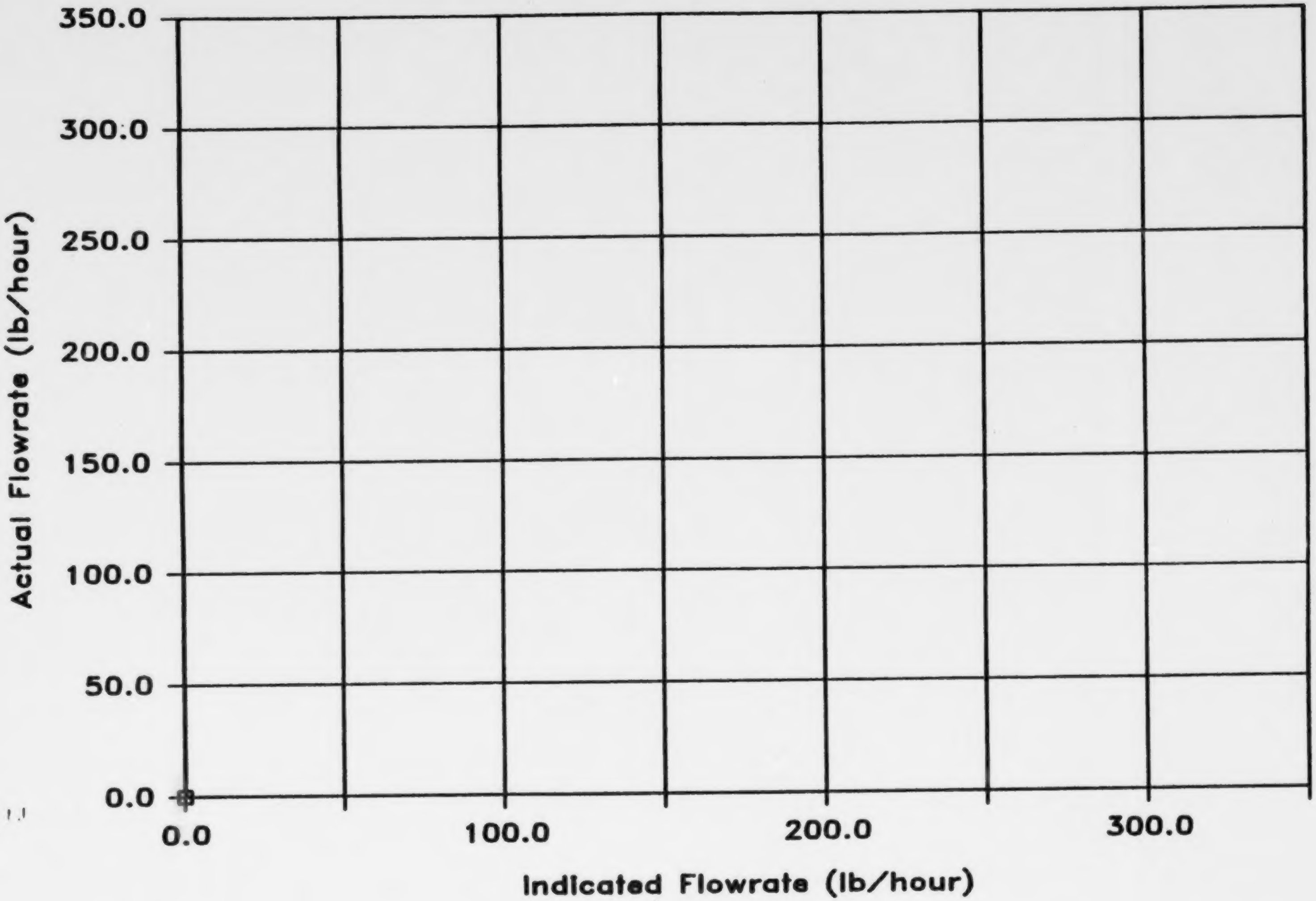
Reference:

Micro-motion model C-12 manual.

Comments:

____

WASTE OIL FLOWRATE CALIBRATION



KILN COMBUSTION AIR FLOWMETER CALIBRATION
Tag # FI-102

Calibration date: _____________

Calibrated by: _____________

Ambient Temperature: ____________
Ambient Pressure: ____________ Flow Pressure: ________________
Relative Humidity: ____________

Instrument linearity

Indicated (SCFM)	Measured Differential (in. H2O)	Computed (SCFM)
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________

Instructions:

1.) Install tee tubing fittings in the signal line between the pressure taps from the Annubar flow sensor and the flow indicator.
2.) Connect an inclined manometer, readable to 0.01 in. water column, to the tee fittings insuring that all fittings are tight.
3.) Energize the combustion air blower.
4.) Adjust the combustion air flowrate to the desired rate and record the pressure differential reading on the manometer and the flowrate on the flow indicator.
5.) Adjust the flowrate to a new level and repeat the flow measurement.
6.) Recommended calibration points - 500,700,900,1100,1300,1500,& 1100 SCFM.
7.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate or replace the flowmeter.

SAVE ALL CALIBRATION DATA

Formula:
Use Annubar Flow Calculator provided with flowmeter.

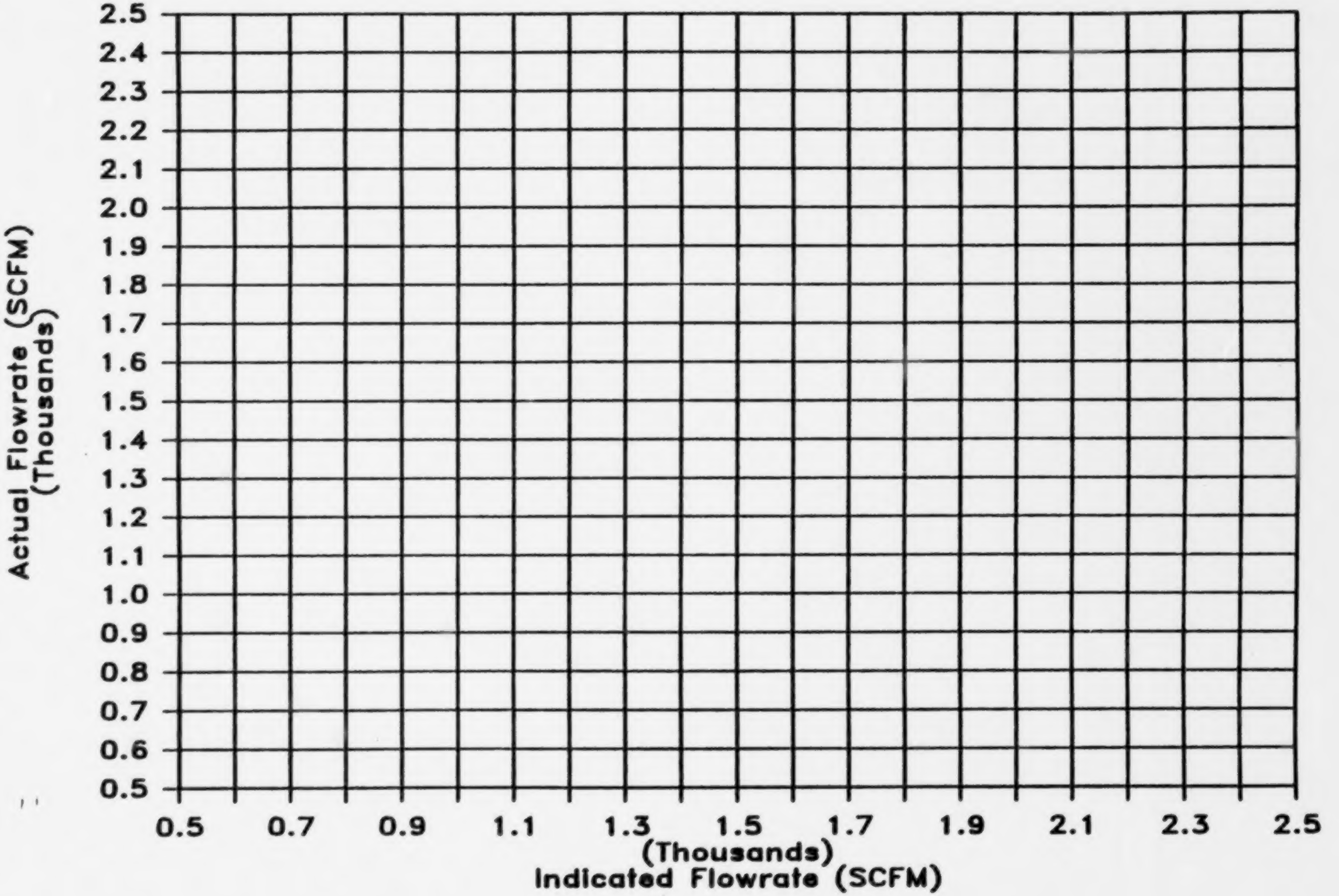
Reference:
Annubar Flow Handbook, Dietrich Standard Corporation

Comments:

____

____

COMBUSTION AIR FLOWRATE CALIBRATION



SCC COMBUSTION AIR FLOWMETER CALIBRATION
Tag # FI-201

Calibration date: ____________

Calibrated by: ____________

Ambient Temperature: ____________
Ambient Pressure: ____________ Flow Pressure: ____________
Relative Humidity: ____________

Instrument linearity

Indicated (SCFM)	Measured Differential (in. H2O)	Computed (SCFM)
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________
_________	_________	_________

Instructions:

1.) Install tee tubing fittings in the signal line between the pressure taps from the Annubar flow sensor and the flow indicator.
2.) Connect an inclined manometer, readable to 0.01 in. water column, to the tee fittings insuring that all fittings are tight.
3.) Energize the combustion air blower.
4.) Adjust the combustion air flowrate to the desired rate and record the pressure differential reading on the manometer and the flowrate on the flow indicator.
5.) Adjust the flowrate to a new level and repeat the flow measurement.
6.) Recommended calibration points - 500,700,900,1100,1300,1500,& 1100 SCFM.
7.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate or replace the flowmeter.

SAVE ALL CALIBRATION DATA

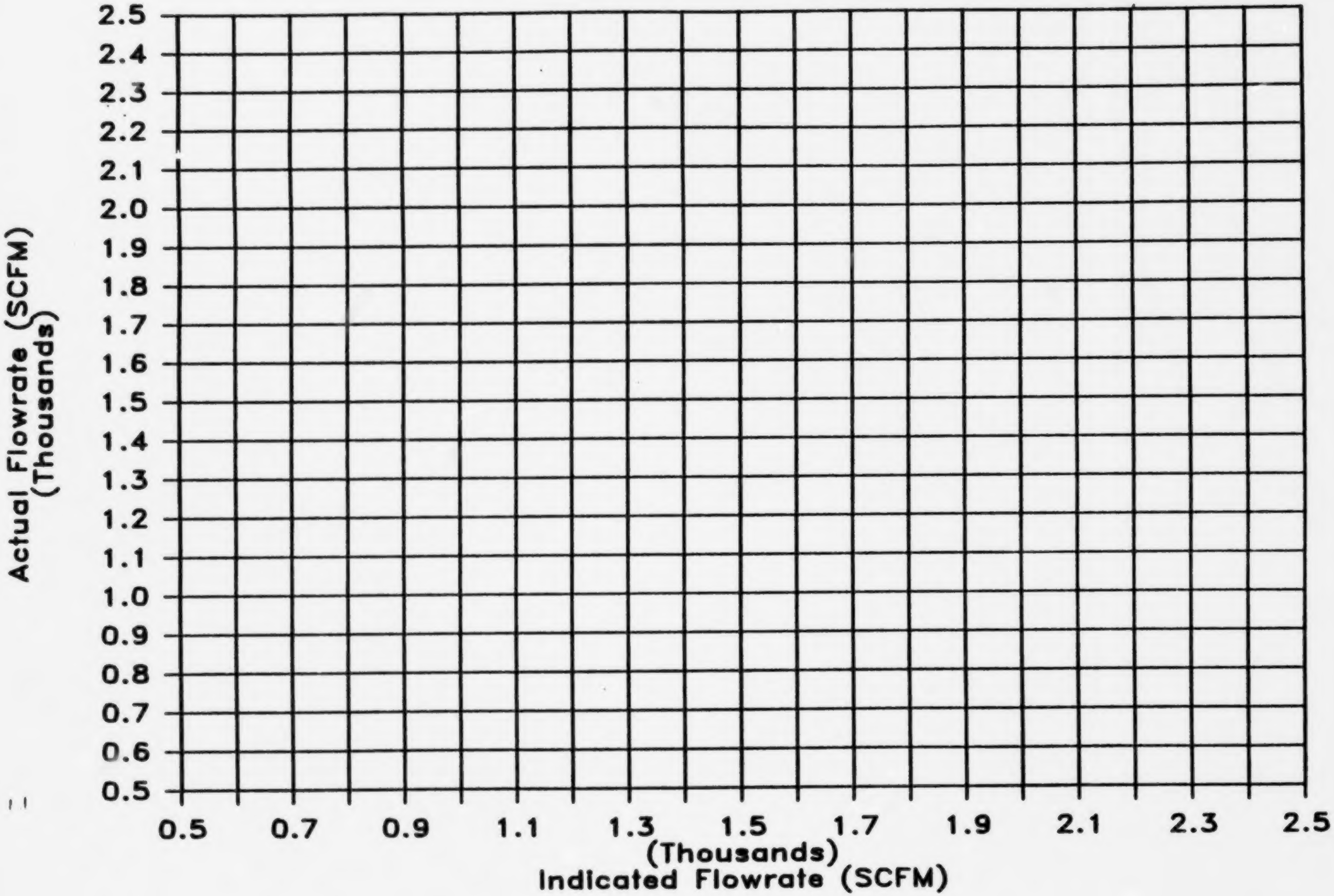
Formula:
Use Annubar Flow Calculator provided with flowmeter.

Reference:
Annubar Flow Handbook, Dietrich Standard Corporation

Comments:
____

____

COMBUSTION AIR FLOWRATE CALIBRATION



KILN TEMPERATURE CALIBRATION
Tag # TIC-101

Calibration date: ___________

Calibrated by: ___________

Instrument linearity

Indicated Temp. (deg F)	Input Signal (millivolt)	Actual Temp. (deg F)
---------	6.91	1400
---------	7.21	1450
---------	7.51	1500
---------	7.82	1550
---------	8.13	1600
---------	8.44	1650
---------	8.75	1700
---------	9.06	1750
---------	9.38	1800
---------	9.70	1850
---------	10.02	1900

Instructions:

1.) Disconnect the thermocouple leads form the Hy-Cal signal transmitter and connect the leads from the output from a precision millivolt source, accurate and adjustable to 0.01 millivolts, observing the proper lead polarity.

2.) Energize the temperature instrument power circuits.

3.) Adjust the millivolt source to the desired output for a specific temperature (refer to thermocouple chart or the specific data listed above.)

4.) Record the temperature indicated on the temperature indicator/controller.

5.) Adjust the millivolt source to a new level and repeat the measurement.

6.) Recommended calibration points - 1400,1450,1500,1550,1600, 1650,1700,1750,1800,1850,& 1900 deg. F.

7.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate instrument according to manufacturers instructions or replace the thermocouple circuit. Calibrate the new or adjusted circuit using new form.

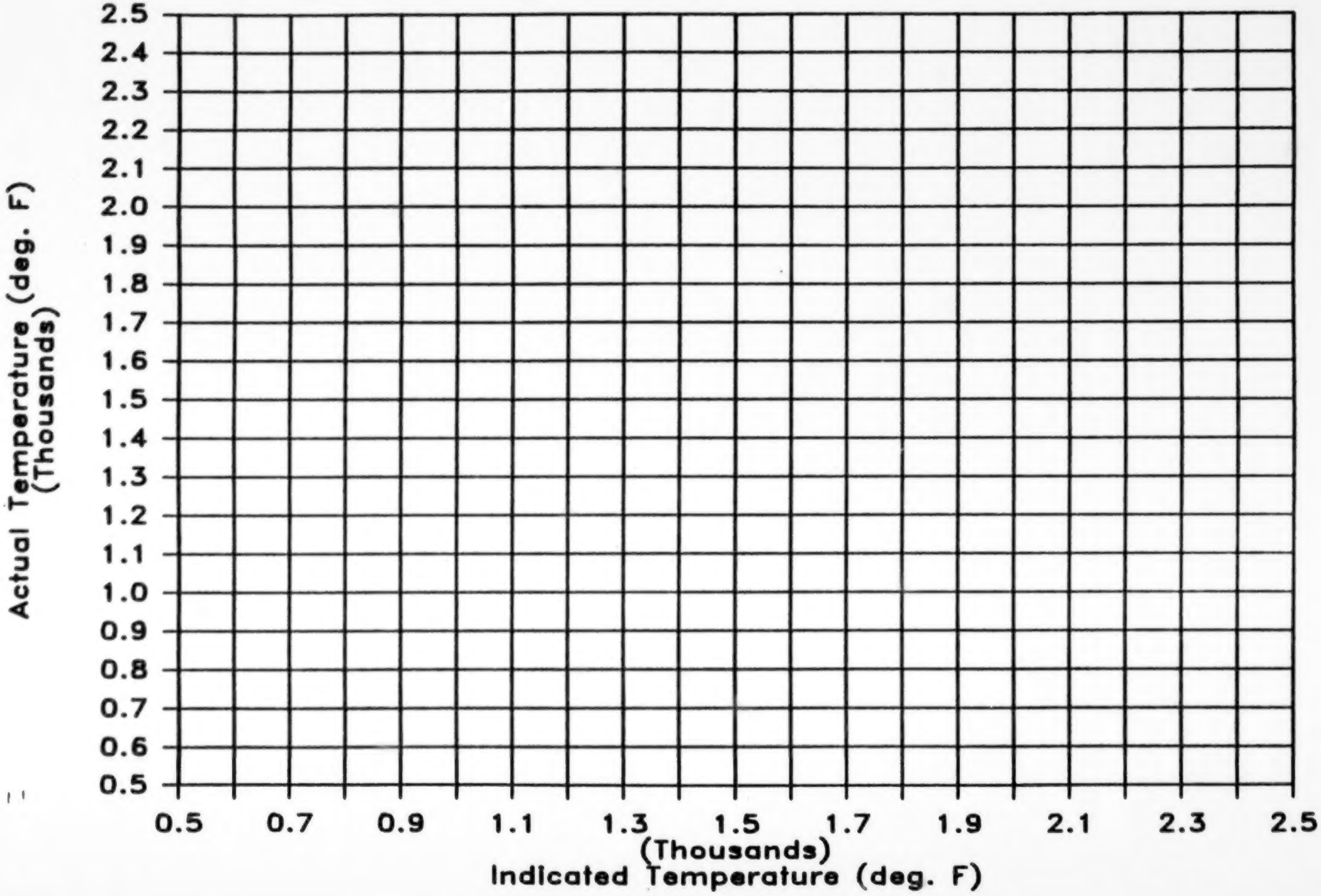
SAVE ALL CALIBRATION DATA

Reference:
NBS or ANSI thermocouple tables for type S (Pt vs. Pt-10%Rh).

Note:
If calibrated thermocouples are used attach calibration data to this sheet.

Comments: ____

TEMPERATURE CALIBRATION



SCC TEMPERATURE CALIBRATION
Tag # TIC-201

Calibration date: __________

Calibrated by: __________

Instrument linearity

Indicated Temp. (deg F)	Input Signal (millivolt)	Actual Temp. (deg F)
_________	10.67	2000
_________	11.00	2050
_________	11.33	2100
_________	11.67	2150
_________	12.00	2200
_________	12.34	2250
_________	12.67	2300
_________	13.01	2350
_________	13.35	2400

Instructions:

1.) Disconnect the thermocouple leads form the Hy-Cal signal transmitter and connect the leads from the output from a precision millivolt source, accurate and adjustable to 0.01 millivolts, observing the proper lead polarity.

2.) Energize the temperature instrument power circuits.

3.) Adjust the millivolt source to the desired output for a specific temperature (refer to thermocouple chart or the specific data listed above.)

4.) Record the temperature indicated on the temperature indicator/controller.

5.) Adjust the millivolt source to a new level and repeat the measurement.

6.) Recommended calibration points - 2000,2050,2100,2150,2200 2250,2300,2350,& 2400 deg. F.

7.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate instrument according to manufacturers instructions or replace the thermocouple circuit. Calibrate the new or adjusted circuit using new form.

SAVE ALL CALIBRATION DATA

Reference:

NBS or ANSI thermocouple tables for type S (Pt vs. Pt-10%Rh)

Note:

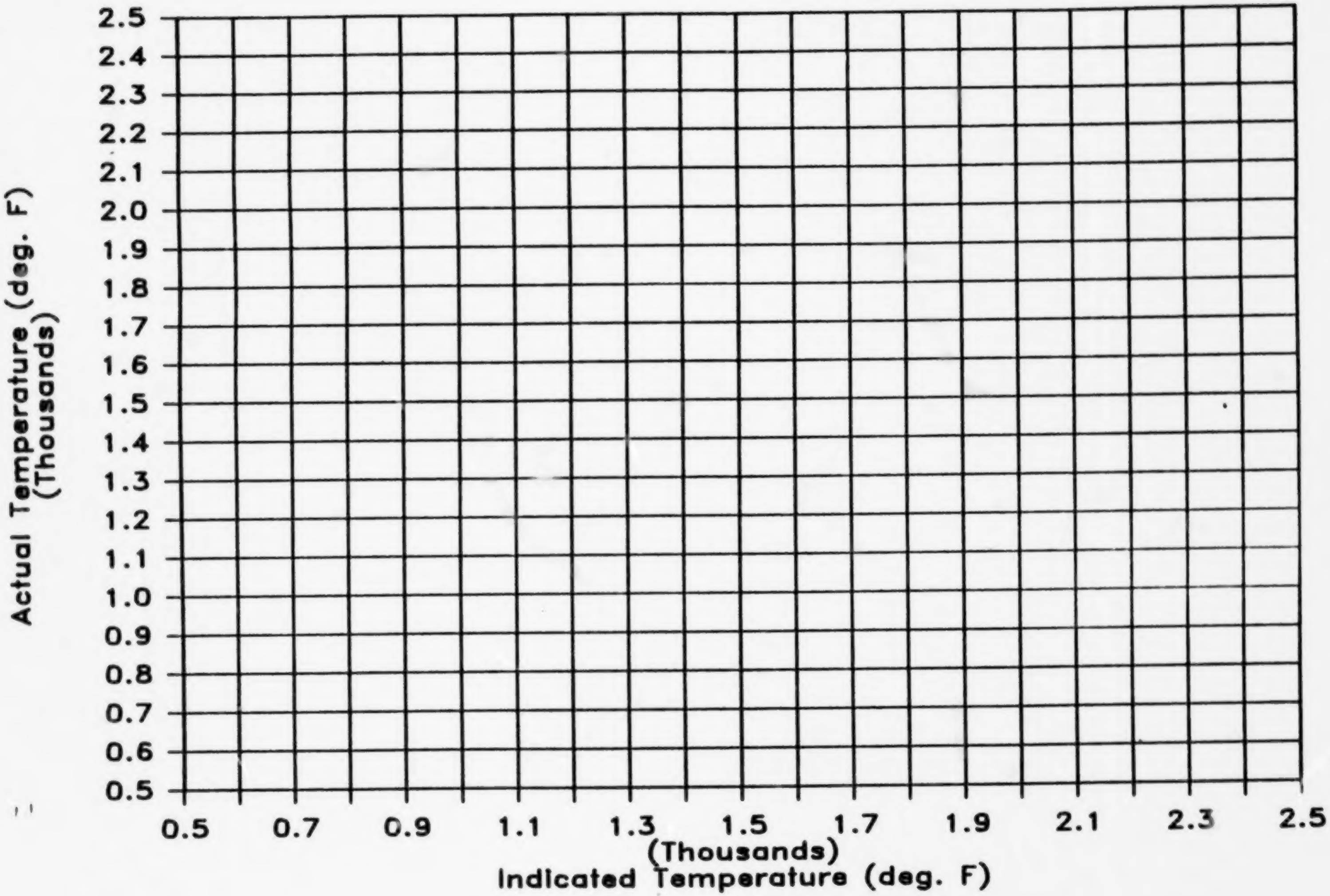
If calibrated thermocouples are used attach calibration data to this sheet.

Comments:

____

____

TEMPERATURE CALIBRATION



KILN WATER INJECTION FLOWMETER CALIBRATION
Tag # FI-106

Calibration date: ----------------

Calibrated by: ----------------

Instrument linearity

Indicated (gal/min)	Measured (ml/sec)	Converted (gal/min)
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------
---------	-------/-------	---------

Instructions:

1.) Disconnect transfer hose on outlet of rotameter and connect tubing to allow collection of water.
2.) Energize kiln water spray transfer system.
3.) Adjust water spray flowrate to desired rate and collect the the discharged water in a 2-liter graduated cylinder. Graduated cylinder must have a tolerance of 10 mL and be graduated "To Contain" volume of liquid.
4.) Collect a minimum of 1500 mL while measuring time with a stopwatch.
5.) Record the volume of water collected and elapsed time.
6.) Adjust the flowrate to a new level and repeat the flow measurement.
7.) Recomended calibration points - 0.6,0.8,1.0,1.2,1.4,1.6 & 1.8 gal/min.
8.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous data then recalibrate or replace rotameter.

SAVE ALL CALIBRATION DATA

Formula:

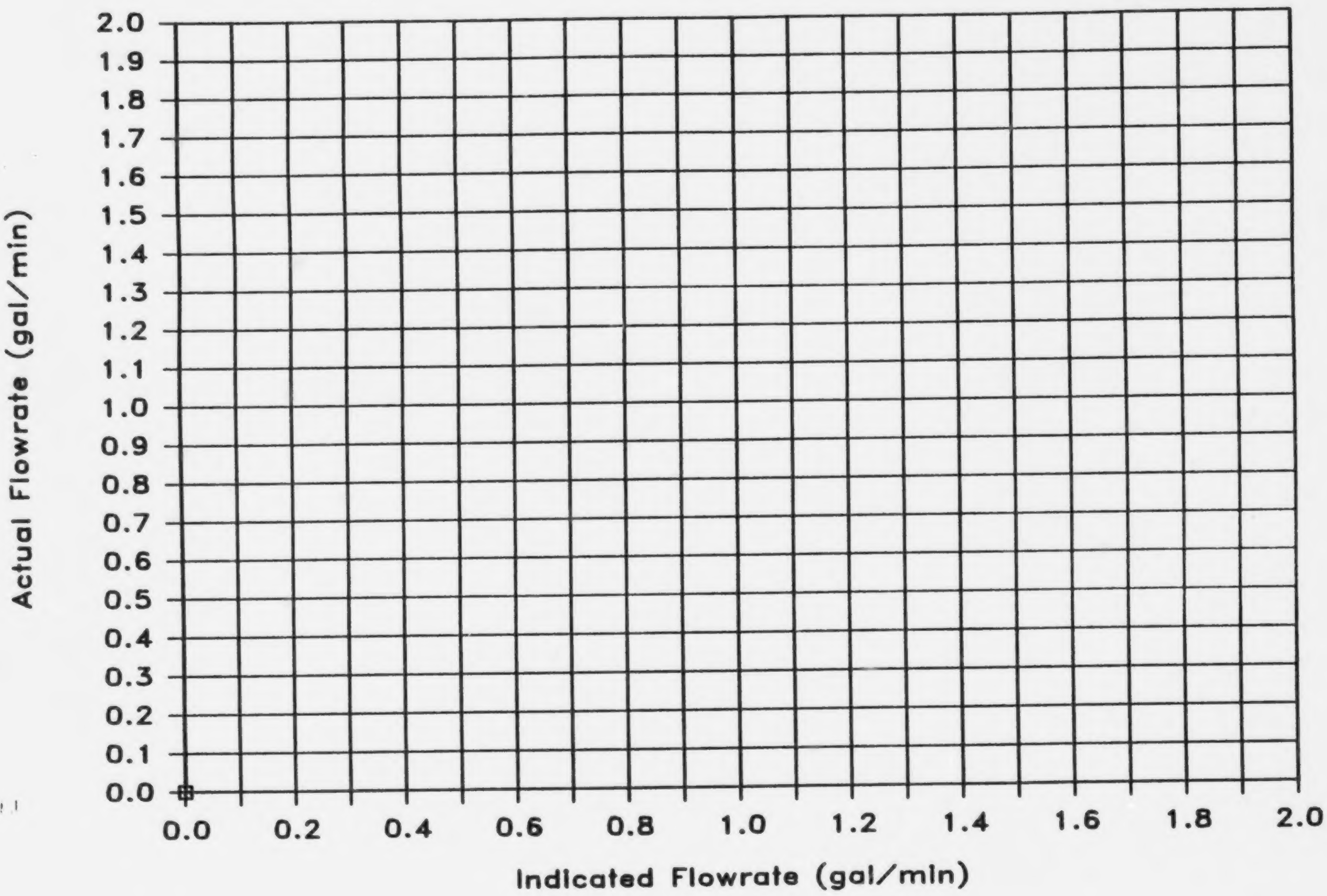
Measured flow (mL/sec) x 0.01585 = flowrate (gal/hr)

Reference:

Dwyer flowmeter manual

Comments:

WATER SPRAY FLOWRATE CALIBRATION



WASTE SOLIDS FEED CALIBRATION
[weight per charge]

Calibration Date: _______________

Calibrated by: _______________

Instrument linearity

Indicated Weight (lb)	Actual Weight (lb)
---------	---------
---------	---------
---------	---------
---------	---------
---------	---------
---------	---------
---------	---------
---------	---------

Instructions:

Calibration of weigh cells to be performed by a licensed weigh system technician.

Attach technician service record to this sheet.

QUENCH pH CALIBRATION
Tag # PHIC-335

Calibration date: __________________

Calibrated by: __________________

Instrument linearity

Indicated pH	Actual pH
_________	4.0
_________	7.0
_________	10.0

Instructions:

1.) Energize pH instrument power circuits.
2.) Remove pH probe from probe holder and rinse with deionized water.
3.) Rinse probe with pH 4.0 buffer solution.
4.) Immerse pH probe into beaker with pH 4.0 buffer solution.
5.) Record pH indicated.
6.) Remove pH probe from beaker and rinse with deionized water.
7.) Rinse probe with pH 7.0 buffer solution.
8.) Immerse pH probe into beaker with pH 7.0 buffer solution.
9.) Record pH indicated.
10.) Remove pH probe from beaker and rinse with deionized water.
11.) Rinse probe with pH 10.0 buffer solution.
12.) Immerse pH probe into beaker with pH 10.0 buffer solution.
13.) Record pH indicated.
14.) Remove pH probe from beaker and rinse with deionized water.
15.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate the instrument according to manufacturers instructions and prepare a new calibration sheet.

SAVE ALL CALIBRATION DATA

Reference:

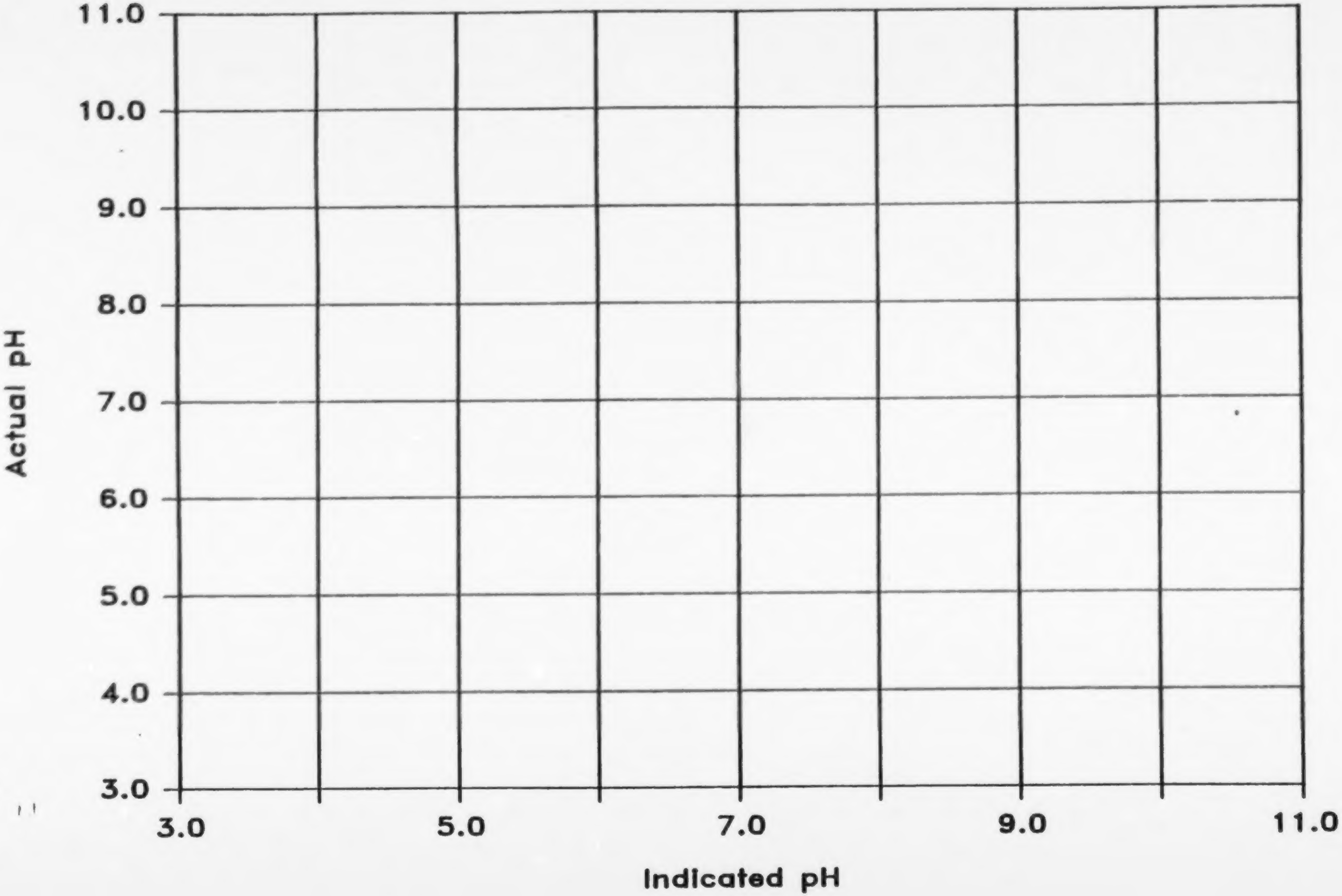
Beckman manual for model 960B pH indcator

Comments:

____

____

pH CALIBRATION



CHEAF pH CALIBRATION
Tag # PHIC-354

Calibration date: __________________

Calibrated by: __________________

Instrument linearity

Indicated pH	Actual pH
__________	4.0
__________	7.0
__________	10.0

Instructions:

1.) Energize pH instrument power circuits.
2.) Remove pH probe from probe holder and rinse with deionized water.
3.) Rinse probe with pH 4.0 buffer solution.
4.) Immerse pH probe into beaker with pH 4.0 buffer solution.
5.) Record pH indicated.
6.) Remove pH probe from beaker and rinse with deionized water.
7.) Rinse probe with pH 7.0 buffer solution.
8.) Immerse pH probe into beaker with pH 7.0 buffer solution.
9.) Record pH indicated.
10.) Remove pH probe from beaker and rinse with deionized water.
11.) Rinse probe with pH 10.0 buffer solution.
12.) Immerse pH probe into beaker with pH 10.0 buffer solution.
13.) Record pH indicated.
14.) Remove pH probe from beaker and rinse with deionized water.
15.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate the instrument according to manufacturers instructions and prepare a new calibration sheet.

SAVE ALL CALIBRATION DATA

Reference:

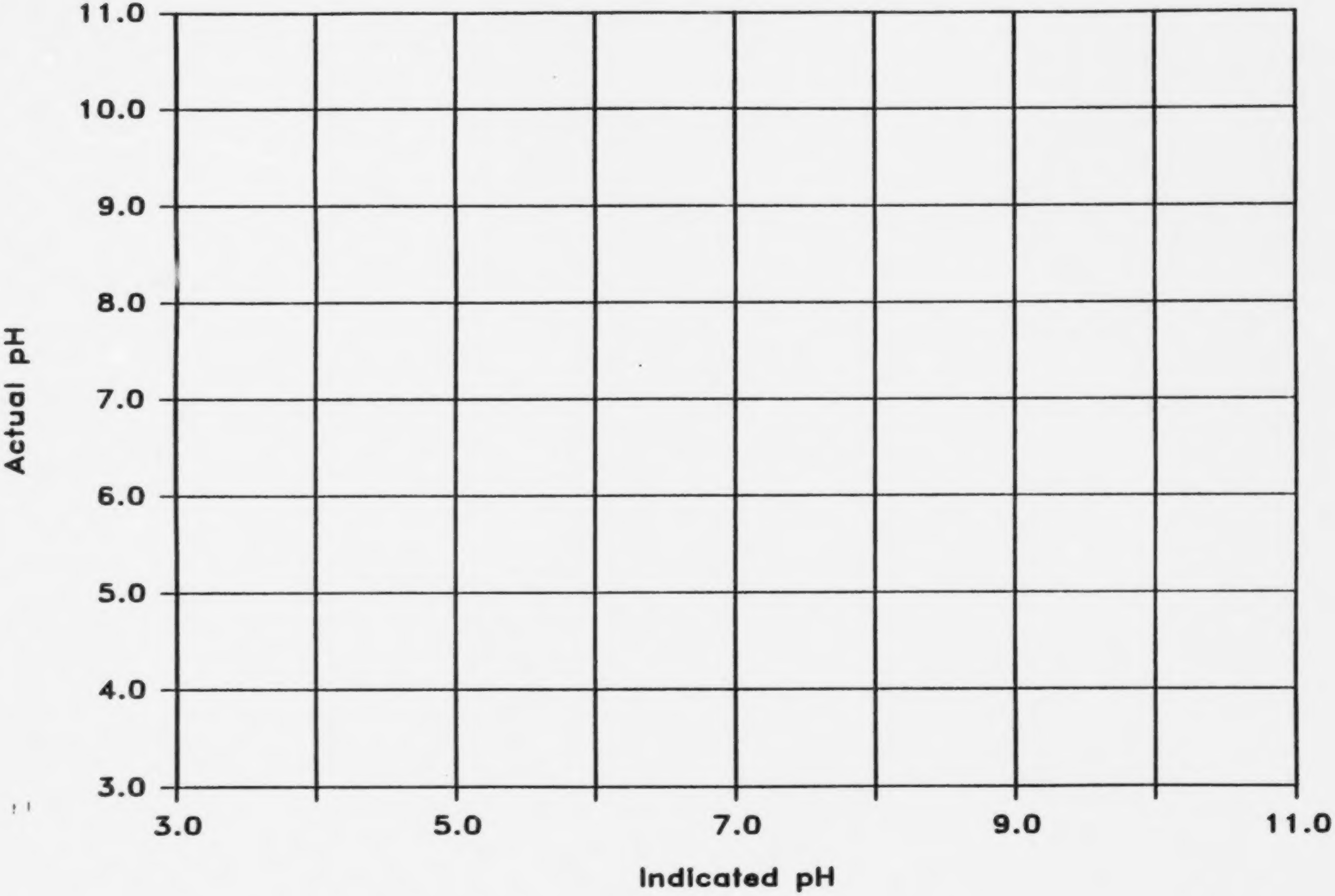
Beckman manual for model 960B pH indcator

Comments:

____

____

pH CALIBRATION



MX SCRUBBER pH CALIBRATION
Tag # PHIC-374

Calibration date: ________________

Calibrated by: ________________

Instrument linearity

Indicated pH	Actual pH
_________	4.0
_________	7.0
_________	10.0

Instructions:

1.) Energize pH instrument power circuits.
2.) Remove pH probe from probe holder and rinse with deionized water.
3.) Rinse probe with pH 4.0 buffer solution.
4.) Immerse pH probe into beaker with pH 4.0 buffer solution.
5.) Record pH indicated.
6.) Remove pH probe from beaker and rinse with deionized water.
7.) Rinse probe with pH 7.0 buffer solution.
8.) Immerse pH probe into beaker with pH 7.0 buffer solution.
9.) Record pH indicated.
10.) Remove pH probe from beaker and rinse with deionized water.
11.) Rinse probe with pH 10.0 buffer solution.
12.) Immerse pH probe into beaker with pH 10.0 buffer solution.
13.) Record pH indicated.
14.) Remove pH probe from beaker and rinse with deionized water.
15.) Plot data points on graph (reverse side) to observe linearity of data. If data appears nonlinear or inconsistent with previous calibration data then recalibrate the instrument according to manufacturers instructions and prepare a new calibration sheet.

SAVE ALL CALIBRATION DATA

Reference:

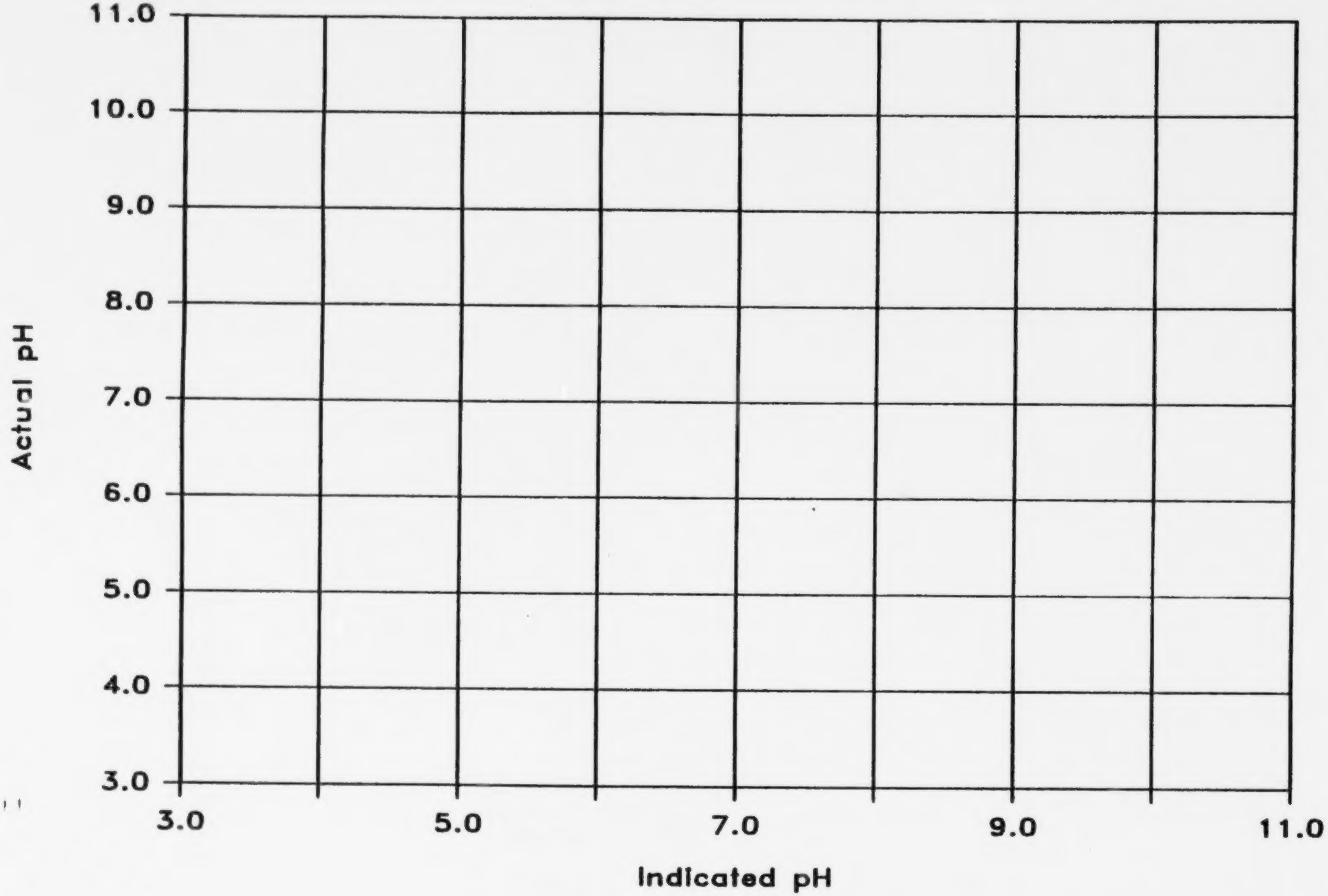
Beckman manual for model 960B pH indcator

Comments:

____

____

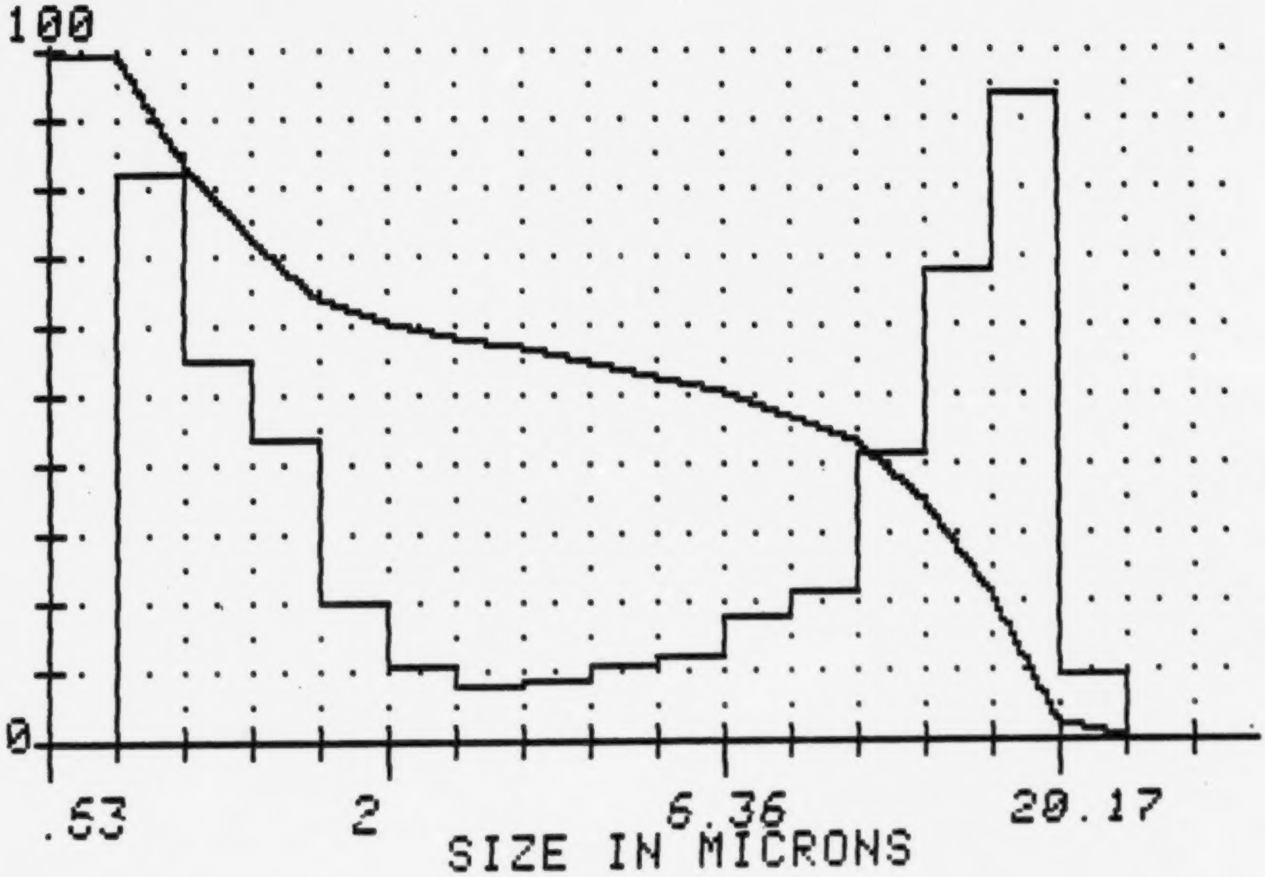
pH CALIBRATION



APPENDIX E

PARTICLE SIZE DISTRIBUTION DATA

```
DATE       :4/9/86
SAMPLE     :FW-18
ELECTROLYTE:ISO
DISPERSANT :B-3
SAMPLE DESC:SCC-1(-20UM)
APERTURES  :50
OPERATOR   :FCA
COMMENTS   :-
LOWER LIMIT:.63
```



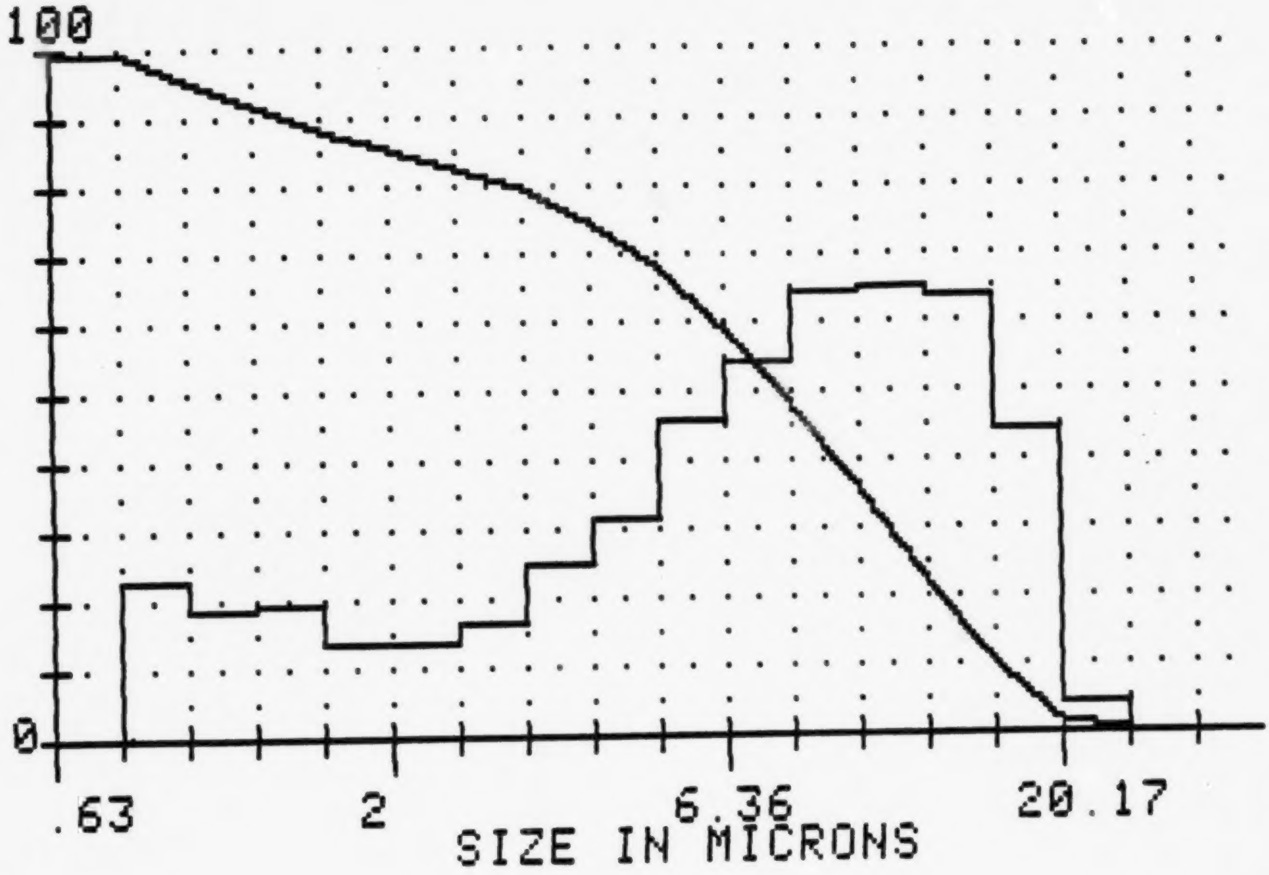
Sample Description:

Ash from SCC after incinerating Denney Farm soil

```
ANOTHER? (Y/N)

     DATE         :4/9/86
     SAMPLE       :FW-18
     ELECTROLYTE:ISO
     DISPERSANT  :B-3
     SAMPLE DESC:SCC-1(-20UM)
     APERTURES   :50
     OPERATOR    :FCA
     COMMENTS    :-
     LOWER LIMIT:.63

     CH     SIZE          VALUE        CUM.
     4      .63           0            100
     5      .79           16.5049      100
     6      1             11.0302      83.4951
     7      1.26          8.71090001   72.4649
     8      1.59          3.9644       63.754
     9      2             2.1305       59.7896
     10     2.52          1.4563       57.6591
     11     3.18          1.6181       56.2028
     12     4.01          2.1036       54.5847
     13     5.05          2.3463       52.4811
     14     6.36          3.479        50.1348
     15     8.01          4.1802       46.6558
     16     10.09         8.3064       42.4756
     17     12.71         13.6462      34.1692
     18     16.01         18.7163      20.523
     19     20.17         1.8069       1.8067
```

```
]RUN REVIEW.D1
ENTER FILE NAME: FW-18


DATE          :4/9/86
SAMPLE        :FW-18
ELECTROLYTE   :ISO
DISPERSANT    :B-3
SAMPLE DESC.:SCC-1(-20UM)
APERTURES     :50
OPERATOR      :FCA
COMMENTS      :-

LOWER LIMIT :.63

HIT RETURN TO CONTINUE
        VOL%        POP
CH:4     0          0
CH:5     61.2       15507
CH:6     40.9       30046
CH:7     32.3       82669
CH:8     14.7       21193
CH       7.9        5318
CH:10    5.4        1640
CH:11    6          954
CH:12    7.8        633
CH:13    8.7        343
CH:14    12.9       256
CH:15    15.5       149
CH:16    30.8       157
CH:17    50.6       127
CH:18    69.4       86
CH:19    6.7        4
```

```
DATE        :4/9/86
SAMPLE      :FW-16
ELECTROLYTE:ISO
DISPERSANT :B-3
SAMPLE DESC:ERVIN FARM-20UM
APERTURES   :50
OPERATOR    :FCA
COMMENTS    :-
LOWER LIMIT:.63
```



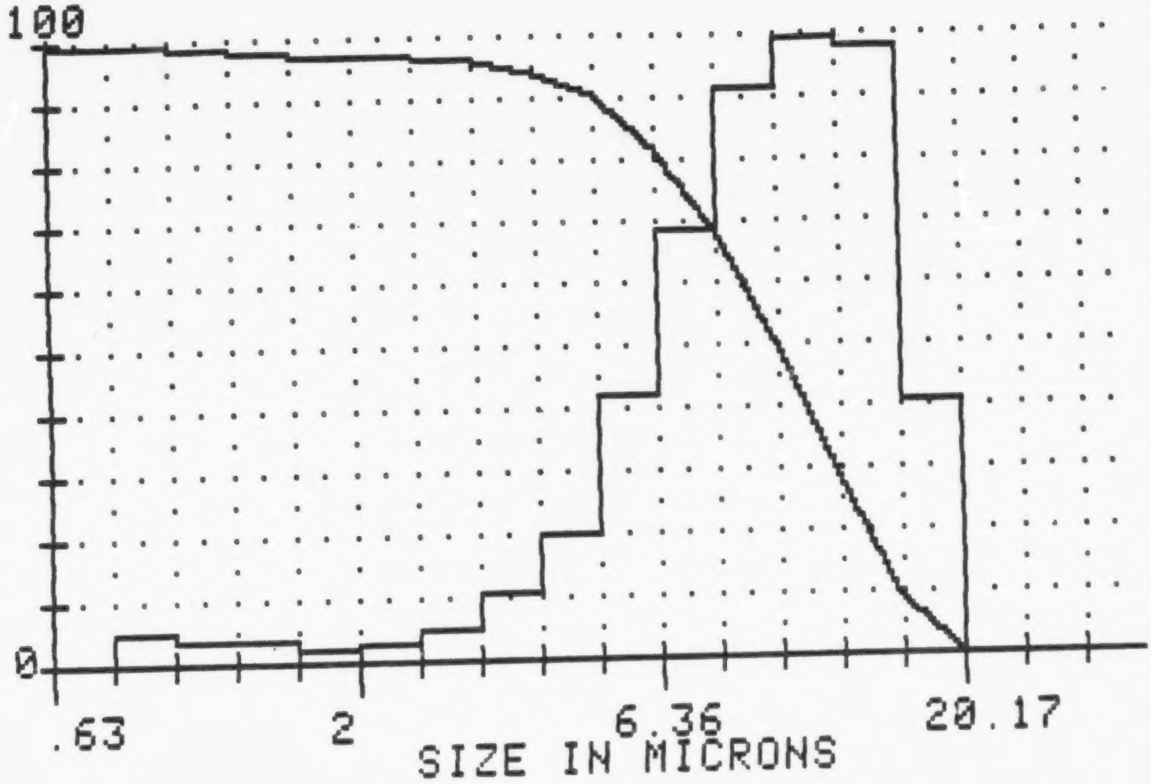
Sample Description:

Ash from SCC after incinerating Erwin Farm soil

```
ANOTHER? (Y/N)
(1) TA II..(2) AGAIN.. (3) STAN..        (4) CONVERT..OR (5) QUIT..:

    DATE        :4/9/86
    SAMPLE      :FW-16
    ELECTROLYTE:ISO
    DISPERSANT :B-3
    SAMPLE DESC:ERVIN FARM-20UM
    APERTURES   :50
    OPERATOR    :FCA
    COMMENTS    :-
    LOWER LIMIT:.63

    CH     SIZE        VALUE       CUM.
    4      .63         0           100
    5      .79         4.5724      100
    6      1           3.631       95.4276
    7      1.26        3.8731      91.7966
    8      1.59        2.7165      87.9235
    9      2           2.6358      85.207
    10     2.52        3.2275      82.5712001
    11     3.18        4.922       79.3437
    12     4.01        6.2937      74.4217
    13     5.05        9.1447      68.128
    14     6.36        10.8392     58.9833
    15     8.01        12.8564     48.1441
    16     10.09       13.0715     35.2877
    17     12.71       12.6681     22.2162
    18     16.01       8.8219      9.5481
    19     20.17       .7262       .7262
```

```
]RUN REVIEW.D1
ENTER FILE NAME: FW-16


DATE          :4/9/86
SAMPLE        :FW-16
ELECTROLYTE   :ISO
DISPERSANT    :B-3
SAMPLE DESC.:ERVIN FARM-20UM
APERTURES     :50
OPERATOR      :FCA
COMMENTS      :-

LOWER LIMIT :.63

HIT RETURN TO CONTINUE
        VOL%         POP
CH:4     0           0
CH:5     17          65406
CH:6     13.5        73771
CH:7     14.4        36604
CH:8     10.1        14200
CH:9     9.8         6612
CH:10    12          3808
CH:11    18.3        2788
CH:12    23.4        1887
CH:13    34          1277
CH:14    40.3        803
CH:15    47.8        479
CH:16    48.6        255
CH:17    47.1        129
CH:18    32.8        43
CH:19    2.7         2
```

DATE :4/9/86
SAMPLE :FW-19
ELECTROLYTE:ISO
DISPERSANT :B-3
SAMPLE DESC:HYDROCYCLONE (- 20 μm)
APERTURES :50
OPERATOR :FCA
COMMENTS :-
LOWER LIMIT:.63



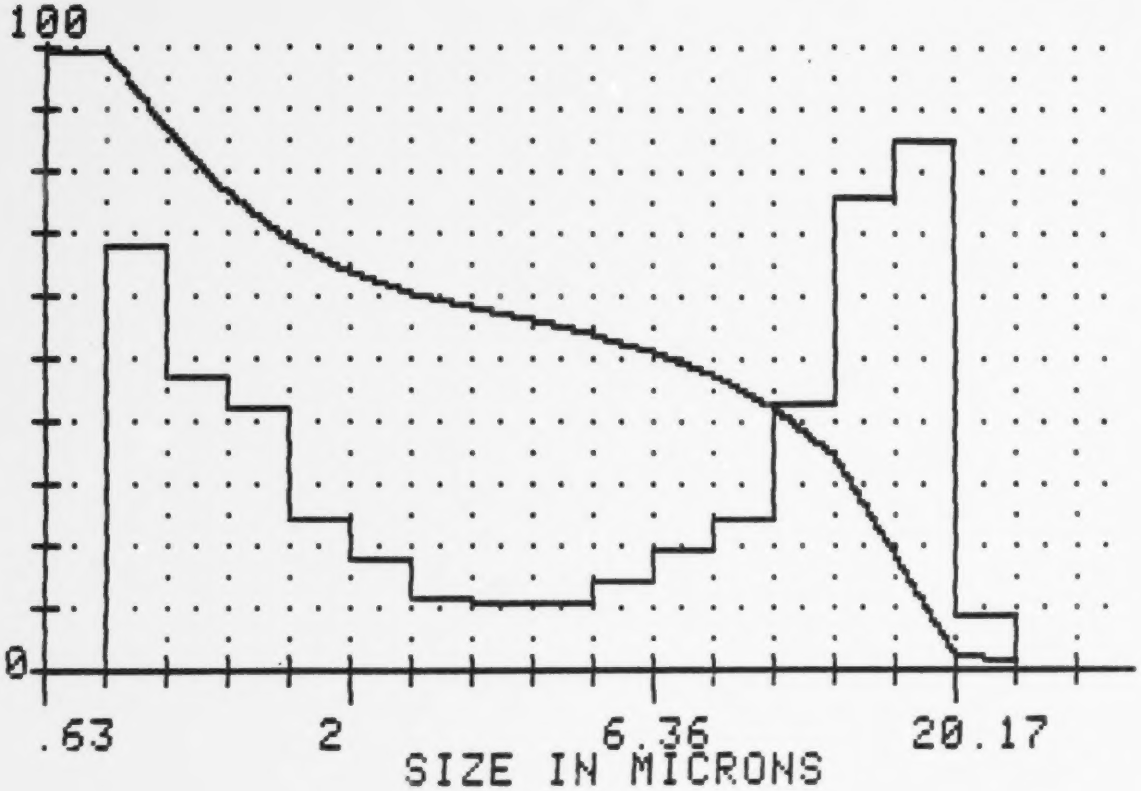
Sample Description:

Ash from hydrocyclone after incinerating Denney Farm soil

```
]RUN REVIEW.D1
ENTER FILE NAME: FW-19


DATE          :4/9/86
SAMPLE        :FW-19
ELECTROLYTE   :ISO
DISPERSANT    :B-3
SAMPLE DESC.  :HYDROCYCLONE(-20 μm)
APERTURES     :50
OPERATOR      :FCA
COMMENTS      :-

LOWER LIMIT :.63

HIT RETURN TO CONTINUE
        VOL%        POP
C' 4      0           0
Ch.5      3.5         39715
CH:6      2.4         15418
CH:7      2.2         6259
CH:8      1.3         2156
CH:9      1.7         1242
CH:10     3.3         1112
CH:11     7.5         1212
CH:12     14.9        1255
CH:13     31.3        1230
CH:14     51.2        1100
CH:15     67.9        737
CH:16     81.1        472
CH:17     72.8        208
CH:18     30.3        45
CH:19     0           0
```

```
ANOTHER? (Y/N)

     DATE          :4/9/86
     SAMPLE        :FW-19.
     ELECTROLYTE:ISO
     DISPERSANT :B-3
     SAMPLE DESC:HYDROCYCLONE (- 20 μm)
     APERTURES   :50
     OPERATOR    :FCA
     COMMENTS    :-
     LOWER LIMIT:.63

     CH      SIZE          VALUE        CUM.
     4       .63           0            100
     5       .79           .9424        100
     6       1             .6462        99.0576
     7       1.26          .5924        98.4114
     8       1.59          .35          97.819
     9       2             .4577        97.469
     10      2.52          .8885        97.0113
     11      3.18          2.0194       96.1228
     12      4.01          4.0118       94.1034
     13      5.05          8.4276       90.0916
     14      6.36          13.7857      81.664
     15      8.01          18.2822      67.8783
     16      10.09         21.8363      49.5961
     17      12.71         19.6015      27.7598
     18      16.01         8.1583       8.1583
     19      20.17         0            0
```

```
DATE        :4/9/86
SAMPLE      :FW-17
ELECTROLYTE:ISO
DISPERSANT :B-3
SAMPLE DESC:SCC-2(-20UM)
APERTURES   :50
OPERATOR    :FCA
COMMENTS    :-
LOWER LIMIT:.63
```



Sample Description:

Ash from SCC after incinerating Denney Farm soil

```
ANI   ER? (Y/N)    _

     DATE          :4/9/86
     SAMPLE        :FW-17
     ELECTROLYTE:ISO
     DISPERSANT  :B-3
     SAMPLE DESC:SCC-2(-20UM)
     APERTURES   :50
     OPERATOR    :FCA
     COMMENTS    :-
     LOWER LIMIT:.63

     CH     SIZE          VALUE         CUM.
     4      .63           0             100
     5      .79           13.5812       100
     6      1             9.4853        86.4188
     7      1.26          8.4883        76.9335
     8      1.59          4.7696        68.4452
     9      2             3.53          63.6756
     10     2.52          2.2366        60.1456
     11     3.18          2.021         57.909
     12     4.01          2.048         55.888
     13     5.05          2.8294        53.84
     14     6.36          3.7726        51.0106
     15     8.01          4.7966        47.238
     16     10.09         8.5691        42.4414
     17     12.71         15.1711       33.8723
     18     16.01         17.0843       18.7012
     19     20.17         1.6168        1.6169
```

```
]RUN REVIEW.D1
ENTER FILE NAME: FW-17


DATE          :4/9/86
SAMPLE        :FW-17
ELECTROLYTE   :ISO
DISPERSANT    :B-3
SAMPLE DESC.  :SCC-2(-20UM)
APERTURES     :50
OPERATOR      :FCA
COMMENTS      :-

LOWER LIMIT :.63

HIT RETURN TO CONTINUE
       VOL%          POP
CH:4     0           0
CH:5     50.4        92726
CH:6     35.2        91079
CH:7     31.5        79162
CH:8     17.7        24624
CH:9     13.1        8733
CH:10    8.3         2574
CH:11    7.5         1159
CH:12    7.6         614
CH:13    10.5        402
CH:14    14          272
CH:15    17.8        169
CH:16    31.8        159
CH:17    56.3        138
CH:18    63.4        83
CH:19    6           4
```